WM. W. FOX, JR.

REPORT OF THE WORKSHOP ON STOCK ASSESSMENT OF PORPOISES INVOLVED IN THE EASTERN PACIFIC YELLOWFIN TUNA FISHERY

(LA JOLLA, JULY 27-31, 1976)

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This report does not constitute a publication and is for information only. All data herein are to be considered provisional.

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1.0 Introduction

On May 11, 1976, Judge Charles R. Richey of the United States District Court, District of Columbia, voided permits issued by the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act of 1972 (MMPA)--PSA/3[1/]--which cover the taking of marine mammals incidental to commercial fishing (PSA/2). In order to comply with certain provisions of the MMPA, Judge Richey ruled that the National Marine Fisheries Service must, among other things, make

> ". . . reasonable estimates of (1) the existing population level of each species of porpoise affected by the proposed regulations, (2) the optimum sustainable population of each of these species, and (3) the expected impact of those regulations on the effort, mandated by the Act, to achieve an optimum sustainable population level for each species." (PSA/2).

The National Marine Fisheries Service assembled experts in population analysis (Appendix 1) to conduct a workshop on porpoise stock assessment (for Agenda, see Appendix 2). The workshop was held July 27-31, 1976, at the Southwest Fisheries Center (SWFC), with the charge that

> ". . . the workshop is to produce estimates of existing population levels, OSP [optimum sustainable population] levels, and the impact of incidental taking on those levels for each and every species or population stock of small cetaceans involved in the U.S. yellowfin tuna purse seine fishery. The workshop shall produce estimates based on what the participants determine to be the best possible analysis

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[1/] Documents presented at the Workshop are listed in Appendix 3 and their references are abbreviated as PSA/Number in this report.

> of information currently available; and therefore, the estimates may range in reliability from those expressed with associated confidence intervals to those representing only the best informed opinions. Each estimate should be labeled as to its reliability and the techniques used to obtain it should be documented." (Memorandum from Robert W. Schoning, Director of NMFS, to Izadore Barrett, Acting Director of SWFC, dated July 21, 1976.)

Under these terms of reference, this report contains estimates of existing population sizes, a determination of the level of existing population relative to its optimum sustainable population, and a determination of the impact of various levels of incidental kill upon the existing population levels relative to the optimum sustainable population level.

2.0 Definition of Optimum Sustainable Population

The participants of the Workshop first addressed the definition of optimum sustainable population (OSP) and considered the documents presented (PSA/2, 3, 10, 20, 21, 24-27). The participants noted that the wording of the MMPA mentions different objectives which are not entirely consistent. In particular, Section 2(6) states that ". . .[marine mammals] should be protected and encouraged to develop to the greatest extent feasible. . . and that consistent with this primary objective [maintaining the health and stability of the marine ecosystem], it should be the goal to obtain an optimum sustainable population. . ."

In Section 3(9) OSP is defined as ". . .the number of animals which will result in maximum productivity. . .keeping in mind the optimum carrying capacity. . .and the health of the ecosystem. . . ." The

participants believe that sound principles of resource management prescribe that "productivity" should be interpreted as net productivity, and for the purposes of the tuna-porpoise problem should be calculated in terms of numbers of animals, with a composition (sex, age, etc.) corresponding to that of the incidental kill. Net productivity is the difference between natural mortality and reproduction. As such, computations of net productivity can be made which indicate that level of take that would allow a population to increase, decrease, or remain stable. The alternatives are gross productivity (simply the total number of births) and productivity per unit population (simply the birth rate per individual). Neither of these alternatives are very useful; gross reproduction is probably maximized at population sizes near, or even above, the carrying capacity of the environment and productivity per unit is maximized near the smallest possible population size. Both alternatives lack the important consideration of natural mortality.

For the tuna-porpoise problem, the population levels required to maximize productivity calculated in terms of numbers will differ little from those calculated in terms of biomass, but these population levels may be substantially below the maximum populations allowed by the carrying capacities--the former could be as little as 50-70% of the latter.

There is therefore a range of population sizes--between that giving the maximum net productivity and the maximum population possible within the carrying capacity of the ecosystem--which appears to be

consistent with the objectives of the MMPA (PSA/24). For the purpose of the Workshop, the optimum sustainable population (OSP) was accepted as being within this range. The participants did not define the upper limit of OSP and consequently used the words "near or above the upper range of OSP" on subsequent sections to reflect the lack of such a specific determination.

The limiting points of the range of OSP are not fixed. Natural environmental changes, and changes imposed on other elements of the ecosystem, e.g., harvesting of tuna, or perhaps the levels of other stocks of porpoises, can change both the carrying capacity, and the population size giving the maximum net productivity (PSA/10). In addition, estimates of all these quantities will be in practice subject to considerable variability. The participants noted that the draft report of the Airlie House Conference (PSA/26, 27) emphasized that use of a resource carries with it the obligation to adhere to four principles: one of these is that "management decisions should include a safety factor to allow for the fact that knowledge is limited and institutions imperfect." It does not seem feasible and perhaps not appropriate to build a safety factor into the definition of optimum sustainable population though some who have considered the problem have taken this approach. The participants have preferred to consider the safety factor (margin for error), which could be built in to allow for the uncertainties

of the models and of the data (see Appendix 4), on a stock-by-stock basis.[2/]

Having conceptually defined OSP and noting that Section 2(2) of the Marine Mammal Protection Act requires that ". . .species should not be permitted to diminish below their optimum sustainable population. . .," the participants recognized that it is important to define the lower limits of the range of OSP, i.e., the population levels giving maximum net productivity (MNP). In practice this characteristic of a natural population is nearly always difficult to determine precisely even when other important characteristics, e.g., the current rate of natural increase, are reasonably well known. This is because, for the MNP level to be estimated directly, estimates are required of the rate of natural increase for several different population levels.

Alternatively the MNP level can be determined indirectly by obtaining estimates of critical population parameters, e.g., gross reproductive rate, at different levels of population. Population

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[2/] Several participants believe that the "margin of safety" principle is best served by accepting the lowest estimate in the range given rather than the midpoint. They emphasized this point in view of the reservations of some participants about the adequacy of the existing data as a basis for safe calculations. Other participants believe that this is entirely unnecessary and should not be applied as a general rule. Decisions should be based on an evaluation of the uncertainties, statistical variations and the impacts of alternatives on a case-by-case basis. This information is provided in subsequent sections of this report.

dynamics theory predicts that net reproductive rate increases to some level with decreasing population level and this increase generates the net natural increase. The form of the relation between population level and these population parameters is critical in determining the precise level of the MNP. If it is linear then the MNP occurs at 50% of the unexploited population. It may well be curvilinear, in which case the MNP may occur at higher or lower levels, depending on whether the curvature is concave or convex. For several stocks of marine mammals, there are sufficient observations to demonstrate clearly that changes in population parameters do occur (PSA/16, 18, 24), but estimates of parameters are rarely available which are accurate enough over a sufficient range of population levels to give much information on the form of the relationship. In particular, they do not show whether or not the relationship is linear.

The simplest logistic model (linear relationship) implies that the level for MNP occurs at 50% of the unexploited population, but some models used for fur seals and both baleen and sperm whales lead to estimates of the level giving MNP to be at 60% or higher percentage of the unexploited population level. It is unclear to what extent such models should be applied to porpoise species and it is unlikely that good estimates for the porpoise stocks will become available in the near future for the porpoise stocks since they would require accurate observations of rate of increase or of population parameters at several

different levels of population. The participants believe therefore that any porpoise stock whose abundance is less than 50% of the unexploited level is probably below the MNP level, and that any stock much more than 70% of the unexploited stock is probably above the MNP level.[3/]

Even though precise estimates of the MNP level are unlikely to become available for most porpoise stocks in the near future, and for some stocks it may be uncertain whether or not the current population is above or below the MNP level, useful advice can still be provided. In particular, the requirements of Sec. 103(d) (2) of the MMPA can still be complied with. This is because for the purpose of determining "the expected impact of the proposed regulations on the optimum sustainable population"--which presumably means the expected changes in the population relative to the optimum sustainable population--the important question is the relation of the expected kill to the net natural population increase. The latter can usually be estimated (within some acceptable limits) even when it is not known what population size (if any) would give a larger net increase. Thus, it can be estimated whether or not some proposed measure (e.g., restricting the kill to a certain level) will allow the population to increase.

[3/] Most of the participants believe that there is insufficient scientific evidence to select a particular value for the proportion of unexploited porpoise population necessary for maximum net production within the range of 50-70%. Subsequent to the Workshop, however, several participants felt that a more definite statement must be made and expressed the opinion that 60% is a prudent approximation. In any event, it should be emphasized that additional scientific information is necessary to firm up this estimate.

The participants noted that, where the relation between present population size and OSP is unknown, a policy of increasing present population levels is a more conservative (i.e., giving a greater margin of safety) approach to implementing the management objectives of the MMPA than would be a policy using the OSP level. This is true because a policy of increasing existing populations may lead to increasing any populations which are already near or above OSP (an objective which is not a requirement of the MMPA), while any populations that are below OSP will also be caused to increase, as is required by the MMPA.

3.0 Stock Assessment

These assessments consider the species and population stocks of porpoises killed incidental to the purse-seine fishery for yellowfin tuna in the eastern tropical Pacific Ocean. This region is bounded on the west approximately by 150°W longitude, on the east by the American continents, on the north approximately by 30°N latitude and on the south approximately by 20°S latitude (Figure 1). The yellowfin tuna regulatory area of the Inter-American Tropical Tuna Commission (IATTC), termed the CYRA, is also outlined for reference in Figure 1.

There are eleven species, comprised of 21 (confirmed or tentative) stocks, of porpoises involved in the purse-seine fishery for yellowfin tuna (Table 1). In addition there is one species, Pacific white-sided dolphin, which is not known to be taken in the yellowfin tuna fishery,

but which has been recorded as taken accidentally by several vessels while fishing for bonito or bluefin tuna outside of the tropical tuna fishery (Table 1). These observations were made in 1976 by NMFS observers aboard those vessels which usually participate in the yellowfin tuna fishery. The participants considered this species to be outside the Workshop's terms of reference

The participants estimated existing population sizes or indices of population size for each of the 21 stocks where data were available (Appendix 5). Then, utilizing estimates of the annual kill (Appendix 6), reproductive rates, natural mortality rates and assessment models (Appendix 7), the population size prior to exploitation and the 1976 population size were calculated to determine their current size relative to the range of optimum sustainable population.

Following the OSP determination, the participants estimated the effects of incidental kill on the existing population sizes relative to their OSP sizes, and estimated the level of kill, below which the current population would increase. The latter estimates are given as the midpoint, or most likely estimate, and as approximate 95% confidence intervals or range estimates where possible. In addition, where a population was determined to be below or within the lower end of the OSP range, the participants determined that level of kill below which it is virtually certain that the current population size will increase. Finally

the participants provided 5-year projections of population change under alternative kill levels and population responses for those stocks which were determined to be below or within the lower range of OSP.

3.1 Spotted Dolphin, *Stenella attenuata*

The spotted dolphin occurs over a wide area. It extends north into the southern half of the Gulf of California (~26°N latitude), along the coast of Peru (to 8°S latitude) and in the eastern Pacific in a broad area stretching to about 150°W longitude, as well as in an outlying area of unknown extension around the Hawaiian Islands and elsewhere in the tropical Pacific (PSA/12). Recently, *S. attenuata* has been taken and sighted in large numbers in an area from 0 to 10°S latitude and to the west of the Galapagos Islands (Fig. 2). The broad range of this species and its common association with yellowfin tuna make it one of the most frequently taken porpoise in the yellowfin tuna fishery. Three stocks of spotted dolphin are found in the region of the yellowfin tuna fishery (PSA/12).

The coastal stock is composed of individuals which in the aggregat are sufficiently different from other spotted dolphins as adults for them to have been described as a separate species (*Stenella graffmani*) in the past. A critical appraisal of the taxonomic status of all Pacific porpoises is underway at the Southwest Fisheries Center and while present results do not warrant the coastal form's separation as a different

species, it clearly belongs to a separate unit stock than does the offshore form (PSA/12). The coastal stock probably occurs from the central Gulf of California to Peru, in a band of unknown width (about 20 miles wide) and is a much smaller stock than the offshore stock (Figures 1 and 2).

The offshore stock (Figures 1 and 2) covers most of the known distribution of *S. attenuata* in the eastern tropical Pacific, an area of 2,600,000 to 3,300,000 million square nautical miles (nm^2). Samples from this stock show morphological characters that distinguish them clearly from the other stocks. Furthermore, morphological clines exist across the region from east to west suggesting that there is incomplete mixing of the population. Tagging data show that porpoises are usually, but not always recaptured within 500 miles of their point of release; therefore, such clines may, on further examination, have some significance in determining whether or not the offshore stock is a single unit stock. Pending such investigations, the participants decided that the offshore spotted porpoise should be treated provisionally as a single unit stock.

Recently the yellowfin tuna fishery has extended to a region west of the coast of South America and to about 10°S latitude. Sightings of spotted dolphins in this region (Figure 2) appear to have a color pattern distinct from those of other stocks. It was decided to treat them tentatively as belonging to a new, and hitherto unexploited stock, the Southwestern stock.

3.1.1 Coastal stock

Although this stock is distinguishable morphologically and ecologically from the offshore stock (PSA/12), identification of samples or individuals is usually not possible without careful examination of specimens on deck. Mortality rates, reproduction rates, and population size of this stock are unknown, and its exact geographic extension is also unknown. Generally, fishermen avoid setting on spotted dolphins close inshore, as they usually carry few tuna and occur in smaller schools than do those further offshore. The coastal stocks may be subject to intensive sporadic local fishing every 2 to 3 years when nearshore schools of unidentified spotted dolphins are found in association with tuna. While the data presently available are sufficient to provide a basis for separating this stock from offshore spotted porpoise as a management unit, the data are insufficient to allow an analysis of the stock.

3.1.2 Offshore stock

3.1.2.1 Initial population size. Calculating initial population size requires at least one estimate of population size, and the net reproductive rates and kill for all years of exploitation.

The estimated population size of the offshore spotted dolphin stock (with approximate 95% confidence limits)[4/] is 3.5 million (2.5 to 4.5 million) as of January 1, 1974 (Appendix 5). Reproductive parameters were estimated in several background documents (PSA/1, PSA/5, PSA/11). The estimates obtained in PSA/11 by Method 2 are believed to be the best. These are:

Year	Gross annual reproduction (%)
1973	13.9
1974	12.8
1975	12.6
Average	13.1
Standard error	0.4

Using Method 1, data on the pregnancy rate from 1971 and 1972 suggest a decline in the gross annual reproduction from levels above 13.9% under the assumption of constant female and reproductive female proportions for those years. However, because Method 2 was preferred, because the change is so slight 1973-1975 and because the years are not significantly different from each other, the participants chose to use the 1973-75 average rounded to 13% with approximate 95% confidence limits of 11 to 15% ($t_{0.05,\ 2df} \times 0.4$).

[4/] While the confidence limits given in this report are an important measure of variability, they are, in most cases, an approximation since the probability distribution of the errors is unknown. In addition, the models used for calculating the variances are, in some cases, an approximation.

The comparison between the spotted dolphin stock off Japan and the stock in the eastern Pacific (PSA/1, PSA/5) was reviewed. The participants agreed that the differences between the two populations resulting in higher gross reproduction rates for the eastern Pacific stock (13% vs 9%) might well be due to exploitation of the eastern Pacific stock. Net annual reproductive rates are calculated from the difference between gross reproductive rates and natural mortality rates. Kasuya (PSA/18) estimated that immature females of the unexploited population of spotted dolphins off Japan experienced a total mortality rate of 3% while that of mature females was 7%. If fishing mortality is indeed zero (and using the higher estimate), natural mortality would also be 7%. However, in a virtually unexploited population at equilibrium the gross reproductive rate and natural mortality must be equal. The gross reproductive rate may be a better estimate than the mortality estimates and, in any case, its selection places the analysis on the safe side. The participants, therefore, decided to accept 9% for natural mortality, which is equal to the value estimated (PSA/18) for the gross reproductive rate in the unexploited Japanese population. The net reproductive rate for the offshore spotted dolphin was therefore estimated at 4% (13% minus 9%). Using the confidence limits on the gross reproductive rate (11 to 15%), the range of 2 to 6% for the net reproductive rate is obtained.

The estimated kill of offshore spotted dolphins 1959-1975 is given in Table 2. The estimated kill 1971-1975 was given by species (Appendix 6), but no species composition information was available prior

to 1971. The fraction of spotted dolphins in the total kill has been relatively stable 1971-1975:

Year	Fraction spotted dolphin
1971	0.580
1972	0.784
1973	0.553
1974	0.625
1975	0.586
Average	0.626
Standard error	0.041

Since no trend was indicated, the participants decided that the best procedure for estimating the total spotted dolphin kill in the period 1959-1970 was to apply the average fraction 0.626 to the total kill during that period (Appendix 6).

Initial population sizes in 1959 were calculated using the 1974 population estimate (3.5 million), the 1974 population estimate plus and minus one and two standard deviations, five values of the maximum net reproductive rate (0.02, 0.03, 0.04, 0.05, 0.06), the annual kill estimates (Table 2) and the assessment models discussed in Appendix 7. Table 3 shows the results for the two possible kill estimates, the three assessment models and the best estimates plus or minus one standard error.

Since the estimates of population size and net reproductive rate are independent, the probability that the true value of both falls more than one standard deviation below the mean estimate is approximately $(0.17)^2$ or 0.03. This is an approximation since we do not know that the estimates follow a normal probability distribution. With this limitation, however, it seems reasonable to consider the range with calculations based on one standard error of the estimates. The midpoint of the initial (1959) estimates is 5.8 million with a range of 5.1 to 6.6 million depending upon which parameters are assumed.

3.1.2.2 1976 population size. The midpoint population size at the start of 1976 was calculated forward from 3,500,000 at the start of 1974 using the midpoint net reproductive rate of 4%, the annual kills for 1974 and 1975 (Table 2), and the models given in Appendix 7. Limits on the midpoint estimate were calculated forward in the same manner as the back-calculated initial population sizes. The midpoint estimate is 3,598,000 with limits of 2,997,000 to 4,221,000 based on one standard error of the population size and net reproductive rate, and 2,417,000 to 4,865,000, based on two standard errors of the parameters

3.1.2.3 Optimum sustainable population determination for 1976. The ratio of the midpoints of the 1976 and 1959 population sizes is 0.62. Using the range of 1959 population sizes (Table 3) and the appropriate corresponding 1976 population estimate, the range of this ratio is from

0.48 to 0.82, with 17 of 18 values following above 0.5 and 5 falling above 0.7. Therefore, the stock of offshore spotted dolphins is most probably within the lower end of the range of optimum sustainable population according to the established criteria.[5/]

3.1.2.4 Impact of incidental mortality on stock. The best estimate of the 1976 population of the combined coastal and offshore stocks of spotted dolphin is 3,598,000 animals. The best estimate of the net reproductive rate (gross reproductive rate less natural mortality) is 4%. Combining these gives a natural addition to the present stock of 144,000 animals annually. Therefore, if these estimates were correct, any kill of less than 144,000 animals would allow the stock to increase.

To account conservatively for statistical variation, however, one standard error below the 1976 population size (2,997,000) and net reproductive rate (3%) were combined, which gives an addition of 90,000 animals annually to the present lower limit of stock size. Thus the participants are reasonably confident that any kill less than 90,000 will allow the stock to increase.

[5/] If, however, 0.60 is selected as a lower bound for OSP (see Footnote 3) and the "margin of safety principle" (see Footnote 2) is accepted, then the lowest ratio estimate suggests that the stock is below OSP.

Account also can be taken of uncertainties and biases in the data and methods of analysis, other than the simple statistical variabili These sources of variability cannot be dealt with in the same quantitative manner as the statistical distributions (see Appendix 4). Limits within which it can be stated with reasonable confidence that the true value (of population size, or rate of increase etc.) can therefore only be set subjectively, bearing in mind the various possible sources of error, e.g., the degree to which the dynamics of the porpoise stocks indeed fit the models and methods of analyses used.

In its discussions the participants examined critically most of the assumptions made and the likely sources of bias. While it is not possible to evaluate these precisely, the participants are reasonably confident that the 1976 population size is at least 2,417,000 and that the net reproductive rate is at least 2%. Therefore, the participants state that in their best judgement if the kill level is held at or below 48,000 (2% of 2,417,000) then the stock is virtually certain to increase.

While the important question regarding the impact of different kill rates is whether they will or will not allow the population to increase, under different combinations of current population size and natural rates of increase, the actual magnitudes of these increases or decreases are also of interest. Calculations were therefore made of the estimated population size, expressed as a percentage of the present

population, for different combinations of annual kill (48,000, 90,000 and 144,000), population size, and net reproductive rate. The new values of population size, expressed as percentages of the 1976 size, after 5 years are set out in Table 4.

Inspection of Table 4 reveals that, at a kill level of less than 48,000 per year, with any population level and at any level of net reproduction rate, the population would be certain to increase. On the other hand, with the least probable combination of unfavorable parameters even the annual kill of 144,000 would only lead to a decrease to 79% of present levels in 5 years. Table 4 also shows what would be the effects of a choice of one kill level if the population level and the net reproductive rates are other than expected. It is clear that, at annual levels of 48,000 to 90,000, the least probable combination of parameters could lead to only a marginal reduction (<11%).

3.1.3 Southwestern stock

The form of spotted dolphin found in the area north of the equator and west of South America, down to 10° to 15°S latitude, appears to be morphologically different from the other forms of *S. attenuata* taken in the yellowfin tuna fishery. High catch rates occur, as would be expected in an area only recently subject to fishing.

The southwestern spotted dolphin stock cannot yet show any significant decline in population levels due to fishing and it must be near or above the upper range of OSP.

3.2 Spinner Dolphin, *Stenella longirostris*

Spinner dolphins occupy a range roughly similar to that of the spotted dolphin (Figures 3 and 4) and appear to comprise four stocks. The Costa Rican stock is a small stock probably occupying a narrow coastal band from about 22° to about 12°N latitude along the coast of Central America. The area occupied by the eastern spinner stock covers most of the CYRA (Figures 3 and 4). This stock has been fished since 1959. The whitebelly spinner stock occupies the south and western area of the range occupied by spotted dolphins and appears to occupy a slightly wider area (Figures 3 and 4). The whitebelly spinner also occupies the tongue of warm water which extends to the west along 10°N latitude. This stock has been fished primarily since 1969. The eastern and whitebelly spinners, because of their different exploitation history, ranges, morphological structures and coloring are clearly separable into two unit stocks and should be subject to separate management.

As for the spotted dolphins, and in the same general area, a separate form has been found recently south of the equator and to the west of South America. It, too, is regarded tentatively as belonging to a new and hitherto unfished stock, the southwestern stock.

3.2.1 Costa Rican stock

The Costa Rican stock is poorly known from just a few specimens (PSA/12). Its color pattern is similar to that of the eastern stock, but the animal as an adult is longer and more attenuate than animals of the eastern stock. While the Costa Rican stock is difficult to identify in the field, it can be clearly separated in laboratory analysis of external and osteological measurements of adequate samples. Kill rates and population sizes for this stock are unknown. The data from the fishery presently available provide no means for separating this stock from the eastern spinner stock as a management unit.

3.2.2 Eastern stock

3.2.2.1 Initial population size. The estimated population size for the eastern spinner stock (with approximate 95% confidence limits) is 1.2 million (0.8 to 1.6 million) as of January 1, 1974 (Appendix 5). A pooled estimate of the gross reproductive rate 1973 to 1975 (10%) was made during the workshop using Method 2 (PSA/11). However, no estimate of natural mortality was available. It was assumed that a population exploited for many years (in this case since 1959) and reduced to the vicinity of 60 percent of its original size (assuming similarity to offshore spotted dolphin) would respond by increasing its net reproductive rate similar to that for the offshore spotted dolphin. The participants, therefore, agreed to use the same maximum net reproductive rates of 2%, 4%, and 6% that were considered appropriate for the offshore spotted dolphin stock.

The annual kill 1959-1975 was estimated in a similar manner as for offshore spotted dolphin (Table 5). The estimated kill was given by species only for 1971-1975 (Appendix 6). The fraction of spinner dolphins in the total kill was relatively stable 1971 to 1975:

Year	Fraction spinner dolphin
1971	0.408
1972	0.187
1973	0.341
1974	0.333
1975	0.359
Average	0.326
Standard error	0.037

Since no trend was indicated, the group decided that the best estimate of total spinner kill for 1959 to 1970 was to apply the average fraction 0.326 to the total kill 1959 to 1970 (Appendix 6). Prior to 1969 the fishery for yellowfin tuna existed virtually only within the CYRA and it was assumed, therefore, that 100% of the spinner kill prior to 1969 was from the eastern spinner stock. In 1974 and 1975 the eastern spinner stock comprised 55% and 40%, respectively of the spinner kill (Appendix 6). A regression line fit to the three points [100% (1968), 55% (1974), 40% (1975)] was used for interpolating the fraction of eastern spinner kill 1969 to 1973 (Table 5).

Initial population sizes in 1959 were calculated using the 1974 population estimate (1.2 million) and for this estimate plus or minus one standard error, and for net reproductive rates of 0.04 (with the best estimate), 0.02 with the lower estimate and 0.06 with the higher estimate (since 2% to 6% is a range rather than confidence interval). Each of these calculations was carried through for two levels of kill estimates (Table 5) and the three assessment models in Appendix 7. The midpoint 1959 estimate is 2.4 million eastern spinner dolphins with a range of 2.0 to 2.7 million (Table 6).

3.2.2.2 1976 population size. The midpoint population size at the start of 1976 was calculated forward from 1,200,000 at the start of 1974 using the midpoint net reproductive rate of 4%, the annual kill for 1974 and 1975 (Table 5), and the models given in Appendix 7. Limits on the midpoint estimate were calculated forward in the same manner as the back-calculated initial population sizes. The midpoint estimate is 1,248,000 with limits of 991,000 to 1,522,000 based on one standard error of the population estimate, and 783,000 to 1,747,000 based on two standard errors.

3.2.2.3 Optimum sustainable population determination for 1976. The ratio of the midpoints of the 1976 and 1959 population sizes is 0.52. Using the range of 1959 population sizes (Table 6) and the appropriate

corresponding 1976 population estimate, the range of this ratio is from 0.37 to 0.75, with 10 of 18 values falling above 0.5 and 1 falling above 0.7. The midpoint and upper range of estimates for the ratio indicate that the stock of eastern spinner dolphins could be within, but very close to the lower end of the range of optimum sustainable population as defined by 0.5. However, since a significant portion of the range of estimates for the ratio fall below 0.5, the stock could well be below the range of OSP[6/].

3.2.2.4 Impact of incidental mortality on stock. Using the midpoint of the estimates, if the kill is kept below 50,000 (4% of 1,248,000), the eastern spinner stock will increase. Accounting conservatively for statistical variability, as with the case of the offshore spotted dolphin, the participants are reasonably confident that the eastern spinner stock will increase if the kill is kept below 20,000 (2% of 991,000). However, as in the case of the offshore spotted dolphin, account also can be taken of uncertainties and possible biases in the data and methods of analysis, i.e., other than statistical variability. Because of the status of the eastern spinner dolphin, uncertainties acquire greater weight in evaluating the likelihood that a given kill

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[6/] If, however, 0.60 is selected as a lower bound for OSP (see Footnote 3) and the "margin of safety principle" (see Footnote 2) is accepted, then the lowest ratio estimate suggests that the stock is probably very much below OSP.

level will affect the stock in a given manner. Again, while it is not possible to evaluate these uncertainties precisely, the participants state that in their best judgement, if the kill level is held at or below 16,000 (2% of 783,000) then the stock of eastern spinner dolphins is virtually certain to increase.

Calculations were made as to the expected changes in population size over the next 5 years under a combination of kill levels (16,000, 20,000 and 50,000), net reproductive rates, and current population sizes (Table 7). Inspection of Table 7 reveals that with the least probable combination of unfavorable parameters (2% net reproductive rate and 783,000 animals), by allowing 50,000 animals to be killed annually, the population will decrease to about 77% of its present size after 5 years. On the other hand, with the least probable combination of favorable parameters (6% net reproductive rate and 1,747,000 animals), an annual kill of 50,000 animals would allow the population to increase to 117% of its present size after 5 years. Even with the least probable combination of unfavorable parameters, if the kill is kept in the range of 16-20,000 it could lead to only a marginal reduction in the population size (<3%).

3.2.3 Whitebelly stock

3.2.3.1 Initial population size. The estimated stock size for whitebelly spinners as of January 1, 1974 is 400,000, with plus and

minus one standard error of 350,000 to 450,000 animals (Appendix 5). Back-calculations were made under the same assumptions as for the eastern spinner stock, except that the initial year of exploitation was 1969 (rather than 1959) so the maximum net reproductive rate obtained under the models (Appendix 7) in 1973 were only 0% to 2.4% (rather than 2% to 6%). This is reasonable assuming roughly comparable natural mortality rates, since the pooled 1973 to 1975 estimate of gross reproduction for whitebelly spinners estimated during the Workshop under Method 2 (PSA/11) was 9% as opposed to 10.2% for the eastern spinner stock. The results using the estimated annual kill (Table 5) are given in Table 8. The midpoint estimate is 517,000 animals in 1969 with a range of 464,000 to 572,000 depending upon the assumed set of parameters.

3.2.3.2 1976 population size. The midpoint population size at the start of 1976 was calculated forward from 400,000 animals in 1974 using the middle reproductive case, the annual kills for 1974 and 1975 (Table 5), and the models given in Appendix 7. Limits on the midpoint estimate were calculated as above (Section 3.2.2.2). The midpoint estimate is 354,000 with limits of 295,000 to 422,000 based on one standard error of the 1974 population estimate and the minimum and maximum reproductive response models.

3.2.3.3 Optimum sustainable population determination for 1976. The ratio of the midpoint 1976 population size estimate to the midpoint of the 1969 population size estimate is 0.68 with a range of 0.63 to 0.78 from selecting the range of 1969 population sizes (Table 8) and the appropriate corresponding 1976 estimate. The whitebelly spinner stock is thus within the range of optimum sustainable population according to the established criteria.

3.2.3.4 Impact of incidental mortality on stock. Using the midpoint of the estimates, if the kill is kept below 7,000 (2% of 354,000) the whitebelly spinner stock will increase. Accounting conservatively for statistical variability the participants are reasonably confident that the stock will increase if the kill is kept below 3,000 (1% of 295,000). The whitebelly spinner stock is in the middle of the OSP range. According to the models and parameter estimates, however, it is necessary at some time in the near future to reduce the average annual kill of 28,000 to prevent the population from reaching the lower limit of the OSP range. For example, if the kill of 28,000 is maintained, the midpoint or most probable estimate is that it must be reduced considerably to 6,555 in the year 1981, or to 9,112 in 1978 on the extreme conservative side, or in more than 10 years on the extreme liberal side, in order to prevent the population from reaching the lower limit of the OSP range according to the established criteria[7/].

[7/] If, however, 0.60 is selected as a lower bound for OSP (see Footnote 3) and the "margin of safety principle" (see Footnote 2) is accepted, then the lowest parameter estimates suggest that the kill should be 13,529 for 1976.

3.2.4 Southwestern stock

This stock is in the same state as the southwestern spotted dolphin stock (Section 3.1.3). Exploitation has just begun so this stock cannot yet show any significant decline in population size due to fishing. Therefore, it must be near or above the upper range of OSP.

3.3 Common Dolphin, *Delphinus delphis*

The distribution of common dolphins in the eastern Pacific is extensive but apparently interrupted. The document by Evans (PSA/15) and recent sightings by NMFS and Navy personnel indicate the possibility of at least six stocks based upon patches of sightings and some morphological characteristics such as relative snout length. The participants regarded these identifications as tentative and determined that at most only four possible stocks need be considered as management units (Figure 5); the northern stock (northeastern Pacific short snout), central stock (Costa Rican short snout), southern stock (South American short snout) and the equatorial-oceanic stock (equatorial oceanic long snout). Each of these stocks is within the range of the tropical tuna fishery but is separated from the others by a hiatus of sightings.

The combined estimate of the tentative northern, central, and southern stocks is 1.4 million (Appendix 5) with approximate 95% confidence limits of 1.2 million to 1.6 million. The average annual kill

1971 through 1975 has been 9,600 animals (Appendix 6). Therefore, even if this kill rate persisted for the full 17 years of the fishery it was probably much less in earlier years), only 163,000 animals would have been killed. Without assuming any increase in the net reproductive rate from zero, the midpoint estimate of the ratio of the present to initial population level is at least 0.90 with a range of 0.88 to 0.91. Therefore, the common dolphin species in the eastern tropical Pacific is near or above the optimum sustainable population range. The average current level of kill is likely to have little or no effect on the existing population size or on its OSP.

It is possible to consider the tentatively identified stocks of this species.

3.3.1 Northern stock

The estimated 1976 population size was 400,000 animals with approximate 95% confidence limits of 310,000 and 490,000 (Appendix 5). The 1974-1976 average annual percentage kill of common dolphins observed by NMFS field technicians within the area of this possible stock was 5% or 480 animals (5% X 9,600) per year. This would be a maximum of 8,200 animals for the 17 years and would have virtually no impact on the stock, i.e., it is near or above the upper range of OSP.

3.3.2 Central stock

The estimated 1976 population size was 230,000 animals with approximate 95% confidence limits of 100,000 to 360,000 (Appendix 5). About 21% of the 1974 to 1976 observed common dolphin kill came from the region identified with this possible stock--2,000 animals per year (21% X 9,600). If the 2,000 animal-per-year kill rate persisted for the whole 17 years of the fishery and if no increase occurred in the net reproductive rate from zero (assuming it was indeed zero), the total kill would have been less than 34,000 animals and the initial or 1959 population size would have been 264,000 animals or less. Comparing the midpoints of current stock size to initial gives the ratio 0.87 at least with a range of 0.75 to 0.91. Therefore, this possible stock would be near or above the upper range of OSP by the accepted criteria, and current levels of kill (2,000 per year) should have little or no impact on the existing or optimum sustainable population.

3.3.3 Southern stock

The estimated 1976 population size was 800,000 animals with approximate 95% confidence limits of 670,000 to 930,000 (Appendix 5). About 74% of the 1974 to 1976 observed common dolphin kill came from the region identified with this possible stock--7,100 animals per year (74% X 9,600). Under the same assumptions as the two stocks addressed above,

the total kill for 17 years would have been less than 121,000 animals and the initial 1959 stock level would have been 921,000 animals or less. Comparing the midpoints of current stock size to initial gives the ratio of at least 0.87 with a range of 0.85 to 0.88. According to the established criteria, this possible stock would be near or above the upper range of OSP and current levels of kill (about 7,100) should have little or no impact on the existing or optimum sustainable populations.

3.3.4 Equatorial-oceanic stock

Common dolphin in these far offshore waters were unknown prior to several research cruises in 1975 and 1976. Any exploitation of these animals has not been observed by NMFS field technicians, therefore the participants believed that this possible stock must be virtually unexploited and, hence, near or above its optimum sustainable population.

3.4 Striped dolphin, *Stenella coeruleoalba*

Striped dolphins range from the tropics to high temperate latitudes. Three possible stocks within the present range of the tropical tuna fishery were tentatively identified (Figure 6) based primarily upon a hiatus of sightings between them--northern stock, north equatorial stock and south equatorial stock. The estimated total 1976 population size for the possible northern and north equatorial stocks combined was

248,000 animals with approximate 95% confidence limits of 127,000 to 369,000 animals. The 1971 to 1975 estimated annual average kill is 718 (Appendix 6). Following the same reasoning as for common dolphin a maximum kill of 12,000 could have occurred over the 17 years of the fishery resulting in a maximum initial population size of 260,000 with a range of 139,000 to 381,000. The ratio of midpoints of the current to initial stock size is at least 0.95 with a range of 0.91 to 0.97 hence the population of striped dolphins in the eastern tropical Pacific is near or above its optimum sustainable population range, and current average kills should have virtually no impact on existing or optimum sustainable populations.

Examination can be made on the basis of the tentatively identified stocks. The same reasoning and methodology was used as for the species as a whole.

3.4.1 Northern stock

The 1976 stock size was estimated at 18,000 (2,000 to 34,000)--Appendix 5. The 1974 to 1976 average kill from this stock was 9% of the total striped dolphin kill or 65 animals per year. The initial stock size was a maximum of 19,000 (3,000 to 35,000) giving a current-to-initial ratio as a midpoint of at least 0.95 (0.67 to 0.97). This possible stock is near or above its optimum sustainable population range and the current average kill should have little or no impact.

3.4.2 North equatorial stock. The 1976 stock size was estimated at 230,000 animals (110,000 to 350,000)--Appendix 5. The 1974 to 1976 average kill from this stock was 91% of the total striped dolphin kill or 653 animals per year. Assuming no net reproduction, the initial stock size was a maximum of 241,000 (121,000 to 361,000) giving a current-to-initial stock size ratio, as a midpoint, of at least 0.95 (0.91 to 0.97). This possible stock is near or above its optimum sustainable population range and the current average kill level should have virtually no impact.

3.4.3 South equatorial stock. This possible stock has only recently (1976) been subject to fishing mortality. The participants believe that this stock must be near or above its optimum sustainable population range.

3.5 Bottlenosed Dolphin, *Tursiops truncatus* and Rough-Toothed Dolphin, *Steno bredanensis*

The bottlenosed dolphin and rough-toothed dolphin are not easily identified separately hence were grouped for the present analysis. No population estimates were made, but the relative sighting index and relative kill index to that of spotted dolphin is sufficient for making a determination of the status of these species. The relative sighting index is 7.53% of spotted dolphin sightings (Appendix 5), and the estimated average number killed per year 1971 to 1975 was only 101 or

0.1% of the 1975 spotted dolphin kill. The opinion of the participants was that this level of kill is likely to have little or no impact on the existing or optimum sustainable population of bottlenosed or rough-toothed dolphins.

3.6 Fraser's Dolphin, *Lagenodelphis hosei*

The relative sighting index of Fraser's dolphins is 0.08% (Appendix 5) and the average estimated annual kill 1971 to 1975 is only five animals (Appendix 6) or 0.005% of the 1975 spotted dolphin kill. The opinion of the participants was that this low average kill would have virtually no impact on the existing or optimum sustainable populati

3.7 Risso's Dolphin, *Grampus griseus*

The relative sighting index is 0.06% (Appendix 5) and the estimated average annual kill 1971 to 1975 was about seven animals or 0.007% of the spotted dolphin kill. The opinion of the participants was that this low average kill would have virtually no impact on the existing or optimum sustainable populations.

3.8 Short-Finned Pilot Whale, *Globicephala macrorhynchus*

The relative sighting index of this pilot whale is 0.44% (Appendix 5). The average estimated annual kill 1971 to 1975 of short-finned pilot whales is grouped with that for the pygmy and melon-headed

whales at about six per year (Appendix 6) or 0.006% of the spotted dolphin kill for 1975. Even if all the estimated kill were short-finned pilot whales, the two orders of magnitude difference between sighting and mortality indices led the participants to conclude, in their best judgement, that the average annual kill has virtually no impact on existing and optimum sustainable populations.

3.9 Pygmy Killer Whale, *Feresa attenuata*

Records of kill of this species are so few (one known juvenile) that the participants concluded that the present kill of this species will likely have no effect on existing or optimum sustainable population.

3.10 Melon-headed Whale, *Peponocephala electra*

As for the pygmy killer whale, records of kill of this species are so few (one known juvenile) that the participants concluded that the present kill of this species will likely have no effect on existing or optimum sustainable populations.

4.0 Essential Research

The participants noted the following essential areas of further work.

4.1 Aerial Survey

An aerial survey of the whole area covered by the major stocks of porpoise subject to the tropical yellowfin tuna fishery is essential. New and regular estimates of population sizes must be made, which should be sufficiently precise to determine whether any particular level of kill that may be allowed is in fact achieving the effects on population level that the Workshop has estimated. The area covered by the survey must include the ranges of the offshore spotted dolphin, the eastern and whitebelly spinner dolphin, and the three tentative stocks of striped dolphin. Particular attention should be paid to the data recording and to the calibration of ship and aerial estimates of school densities, so that, in the future, unbiased estimates can be obtained by either type of survey. Ideally this survey should be repeated at least twice in one calendar year, at different times of year, so as to distinguish seasonal variations in range. Furthermore, this approach requires a long-term commitment because of the small population changes relative to any confidence limit.

4.2 Vital Rates of Unfished Stocks

Immediate determination of the natural mortality and reproduct rates of unfished porpoise stocks in the eastern Pacific should be carried out. The tropical yellowfin tuna fishery is presently entering

a new area and fishing new stocks of porpoises: the Southwestern stocks of spotted and spinner dolphins, the equatorial stocks of striped dolphin, and the equatorial oceanic stock(s) of common dolphin are all relatively unfished stocks. For all of these species, as for almost any species subject to a fishery, estimates of natural mortality are very difficult. However, estimates of total mortality in the unfished condition are equivalent to estimates of natural mortality and are relatively easier to determine. The southwestern stocks of spotted and spinner dolphin, and to a lesser extent the unfished or relatively unfished stocks of striped and common dolphin, should be subject to an intensive research program to determine the value of natural mortality, reproduction parameters, growth rates, and other parameters of interest to their rational management.

4.3 Complete Sampling of Whole Schools

A successful porpoise management program must have a sound biological data base. Essential data cannot be obtained without engaging in scientific fishing of porpoise schools. The mortality of the porpoise during sampling should be minimal. These studies are essential to obtain an adequate data base; for instance, natural mortality cannot be estimated without obtaining unbiased size frequency samples of schools.

4.4 Estimation of School Size

At any given time during the observation of a school of porpoise consisting of large numbers moving simultaneously, a sizeable fraction of the animals is under water. This could lead to a substantial error in estimating school size which is assumed to average out over a large sample. It is essential, therefore, that a carefully designed program be undertaken so as to determine the relation of these estimates to the number that are actually present.

Table 1. List of cetaceans killed incidentally by U.S. tuna purse seiners in the eastern Pacific[1/]

A. In tropical tuna fishery:

1) Spotted dolphin, *Stenella attenuata* (spotter porpoise)

   a. Coastal stock (bull spotter, humpback spotter, untouchables)

   b. Offshore stock

   c. Southwestern stock -- tentative

2) Spinner dolphin, *Stenella longirostris* (spinner porpoise)

   a. Costa Rican stock (untouchables)

   b. Eastern stock (regular spinner)

   c. Whitebelly stock (whitebelly spinner)

   d. Southwestern stock -- tentative

3) Common dolphin, *Delphinus delphis* (whitebelly porpoise)

   a. Northern stock
   b. Central stock
   c. Southern stock
   d. Equatorial-oceanic stock

   } tentative

4) Striped dolphin, *Stenella coeruleoalba* (streaker porpoise, whitebelly porpoise)

   a. Northern stock
   b. North equatorial stock
   c. South equatorial stock

   } tentative

Table 1. (Continued)

5) Bottlenose dolphin, Tursiops truncatus (black porpoise)

6) Rough-toothed dolphin, Steno bredanensis (black porpoise)

7) Fraser's dolphin, Lagenodelphis hosei (whitebelly porpoise)

8) Risso's dolphin, Grampus griseus (blackfish, white whale)

9) Shortfinned pilot whale, Globicephala macrorhynchus (blackfish, pilot whale, bubblehead)

10) Pygmy killer whale, Feresa attenuata (blackfish, black porpoise)

11) Melon-headed whale, Peponocephala electra (blackfish, pilot whale, bubblehead)

B. In temperate wetfish fishery (for bluefin tuna, bonito, mackerel and anchovies)

12) Pacific white-sided dolphin, Lagenorhynchus obliquidens (whitebelly porpoise, hookfin porpoise)

1/ Common and scientific names follow the standards developed by the International Whaling Commission. Additional common names occasionally used by U.S. tuna fishermen follow in parentheses.

Table 2. Estimated kill of spotted dolphin 1959-1975

Year	Kill	
	Higher	Lower
1959	129,000	34,000
1960	534,000	185,000
1961	446,000	223,000
1962	106,000	
1963	133,000	
1964	255,000	
1965	297,000	
1966	281,000	
1967	195,000	
1968	164,000	
1969	331,000	
1970	308,000	
1971	185,000	
1972	273,000	
1973	120,000	
1974	75,000	
1975	106,000	
Total	Higher 3,938,000	
	Lower 3,271,000	

Table 3. Initial population size for 1959 of offshore spotted dolphins (1,000's) under two cases of kill levels, three cases of reproduction responses and three 1974 population levels.

1974 Population Size and maximum net reproductive rate	Kill[1/]	Reproduction Response[2/]		
		I	II	III
3,000,000 - 0.03	Lower	5,051	5,291	5,518
	Higher	5,716	5,958	6,185
3,500,000 - 0.04	Lower	5,106	5,433	5,750
	Higher	5,770	6,100	6,417
4,000,000 - 0.05	Lower	5,125	5,539	5,950
	Higher	5,789	6,206	6,617

[1/] See Table 2.

[2/] Case I = 1-year lag, Case II = 3-year lag, Case III = 5-year lag. See Appendix 7.

Table 4. Offshore spotted dolphin population size after 5 years (as percent of 1976 population size)

Current population	Kill = 144,000			Kill = 90,000			Kill = 48,000		
	I=0.02	I=0.04	I=0.06	I=0.02	I=0.04	I=0.06	I=0.02	I=0.04	I=0.06
2,417,000	79	91	101	89	100	111	100	111	123
2,997,000	85	95	106	95	105	116	102	113	125
3,598,000	89	100	111	97	108	119	103	114	126
4,221,000	92	103	114	99	110	121	104	115	127
4,865,000	95	105	117	101	111	123	105	116	128

Table 5. Estimated kill of eastern and whitebelly spinner dolphins, 1959-1975

Year	Total spinner		Eastern spinner			Whitebelly spinner
	Higher	Lower	% of total spinn.	Higher	Lower	
1959	67,000	18,000	100	67,000	18,000	0
1960	278,000	96,000	100	278,000	96,000	0
1961	232,000	116,000	100	232,000	116,000	0
1962	55,000		100	55,000		0
1963	69,000		100	69,000		0
1964	133,000		100	133,000		0
1965	155,000		100	155,000		0
1966	146,000		100	146,000		0
1967	101,000		100	101,000		0
1968	85,000		100	85,000		0
1969	172,000		(92)	158,000		14,000
1970	160,000		(84)	134,000		26,000
1971	130,000		(76)	99,000		31,000
1972	65,000		(68)	44,000		21,000
1973	74,000		(60)	44,000		30,000
1974	40,000		55	22,000		18,000
1975	65,000		40	26,000		39,000
Totals	2,027,000	1,680,000		1,848,000	1,501,000	179,000

(Brackets denote interpolated data)

Table 6. Initial population size (1000's) in 1959 calculated for Eastern spinner stock for several parameter values.

1974 Population size and maximum net reproductive rate	Kill[1/]	Reproductive Response Case[2/]		
		I	II	III
1,000,000 - 0.02	Higher	2,541	2,606	2,665
	Lower	2,194	2,259	2,318
1,200,000 - 0.04	Higher	2,460	2,587	2,705
	Lower	2,114	2,240	2,358
1,400,000 - 0.06	Higher	2,366	2,549	2,725
	Lower	2,021	2,202	2,378

[1/] See Table 2.

[2/] See footnote 2 of Table 3.

Table 7. Percentage of 1976 population size of eastern spinner dolphins after five years under several kill levels and several net rates of reproduction (I) and present stock sizes.

1976 population size (1,000's)	Annual Kill (1,000's)								
	16			20			50		
	I= 2%	4%	6%	I= 2%	4%	6%	I= 2%	4%	6%
783	100	110	122	97	108	119	77	86	97
991	102	113	124	100	111	122	84	94	105
1,248	104	115	126	102	113	125	89	100	111
1,522	105	116	128	104	114	126	93	104	115
1,747	106	117	129	104	115	127	95	106	117

Table 8. Initial population sizes (1,000's) in 1969 calculated for the whitebelly spinner stock for several parameter values

1974 Population size and maximum net reproductive rate	Reproductive Response Case[1/]		
	I	II	III
350,000 - 0.02	464	470	472
400,000 - 0.04	505	517	522
450,000 - 0.06	544	564	572

[1/] See footnote 2 of Table 3.

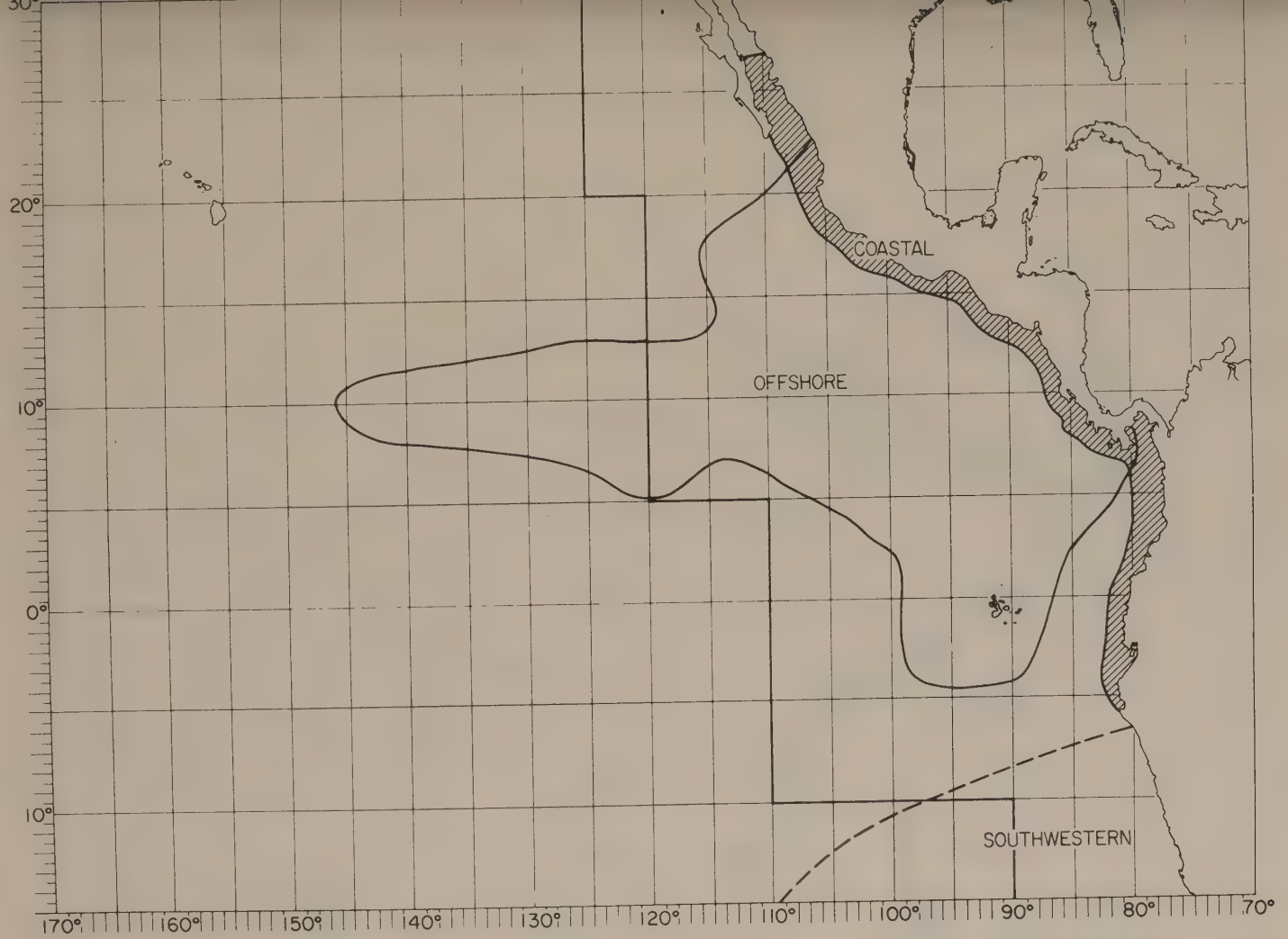
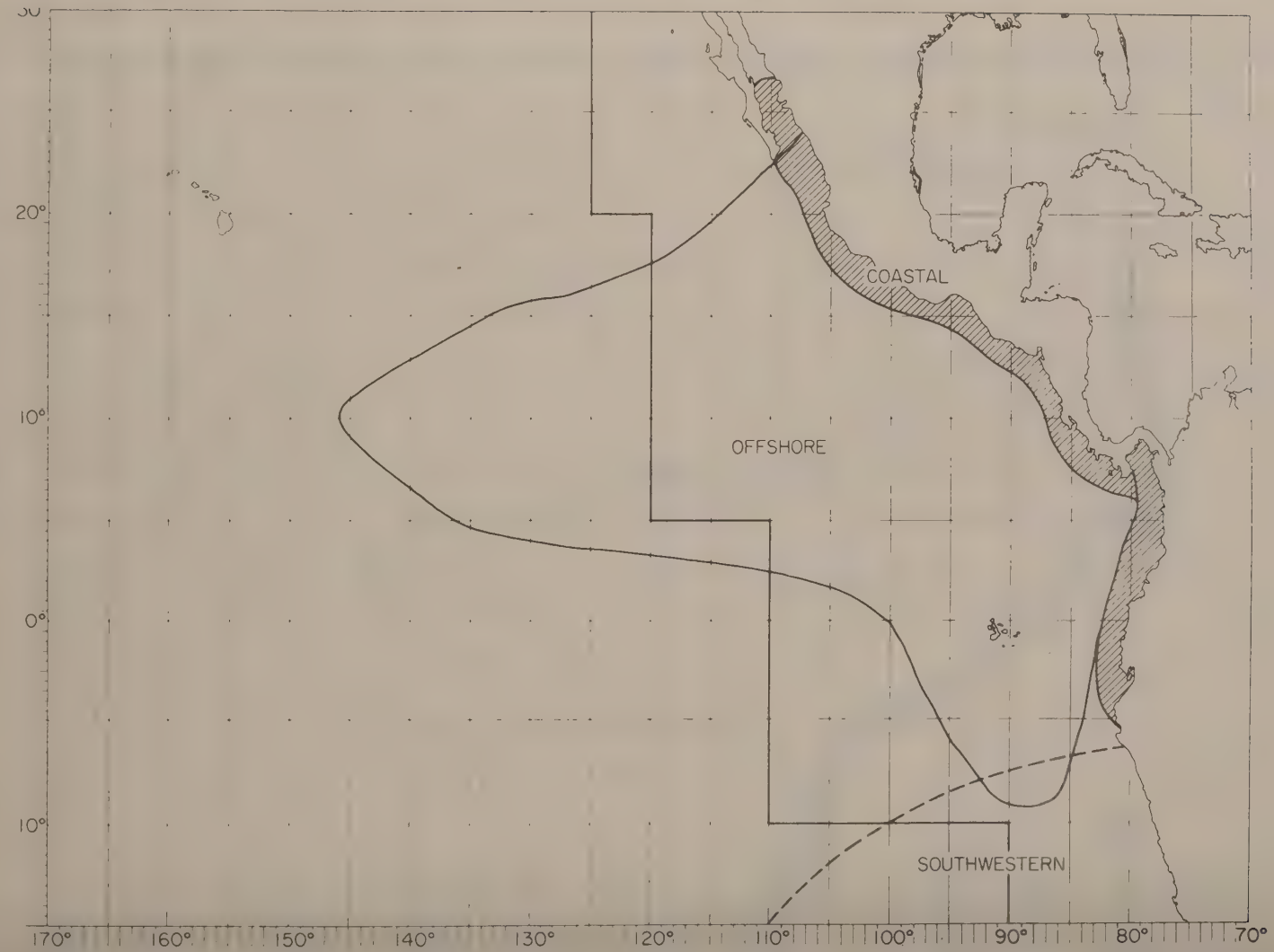


Figure 1. Geographical distributions of stocks of spotted dolphin in the eastern tropical Pacific. Offshore and coastal stocks are given as known in 1973 (PSA/9).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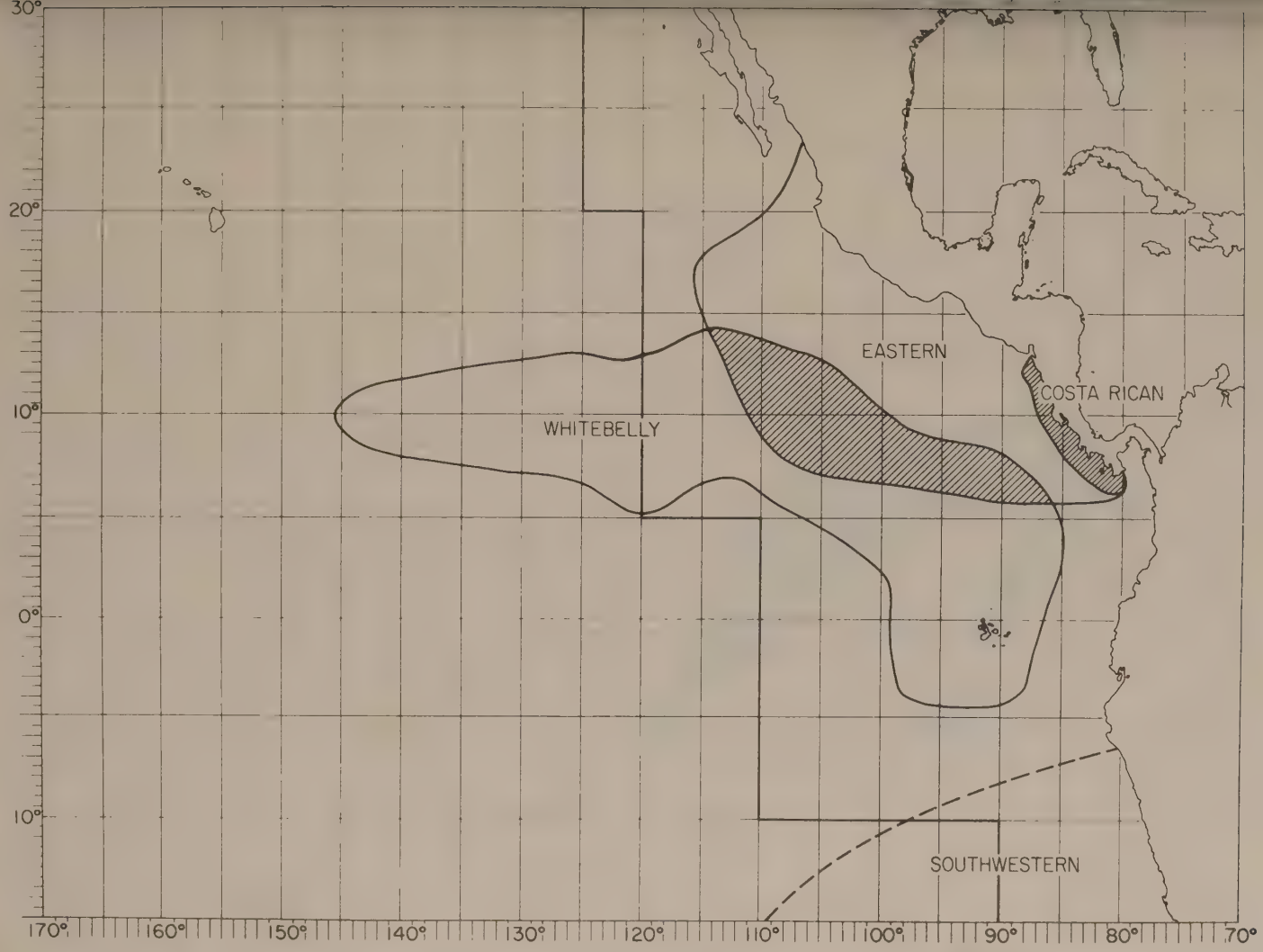
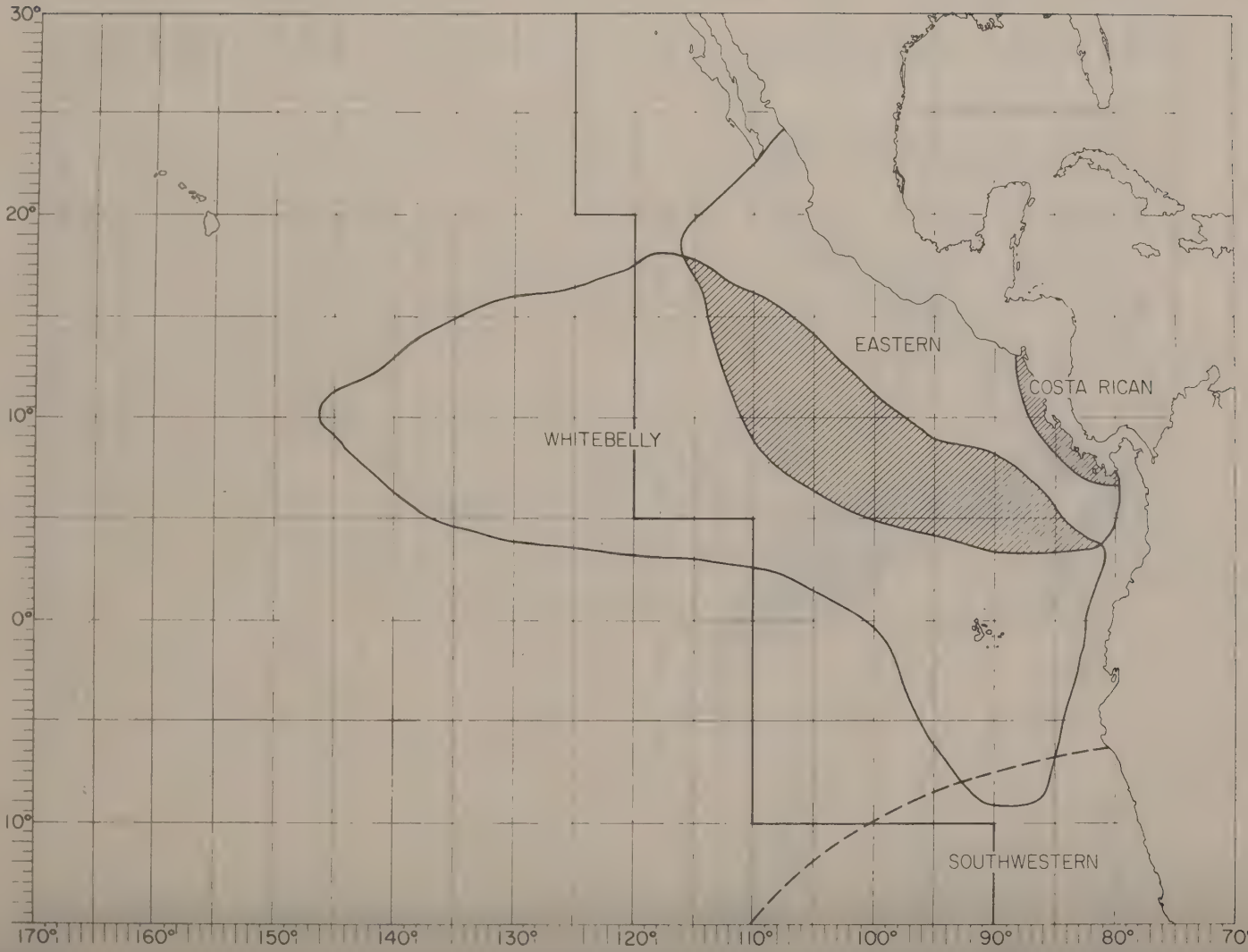


Figure 3. Geographical distributions of stocks of spinner dolphin in the eastern tropical Pacific. Eastern and whitebelly stocks are given as known in 1973 (PSA/9).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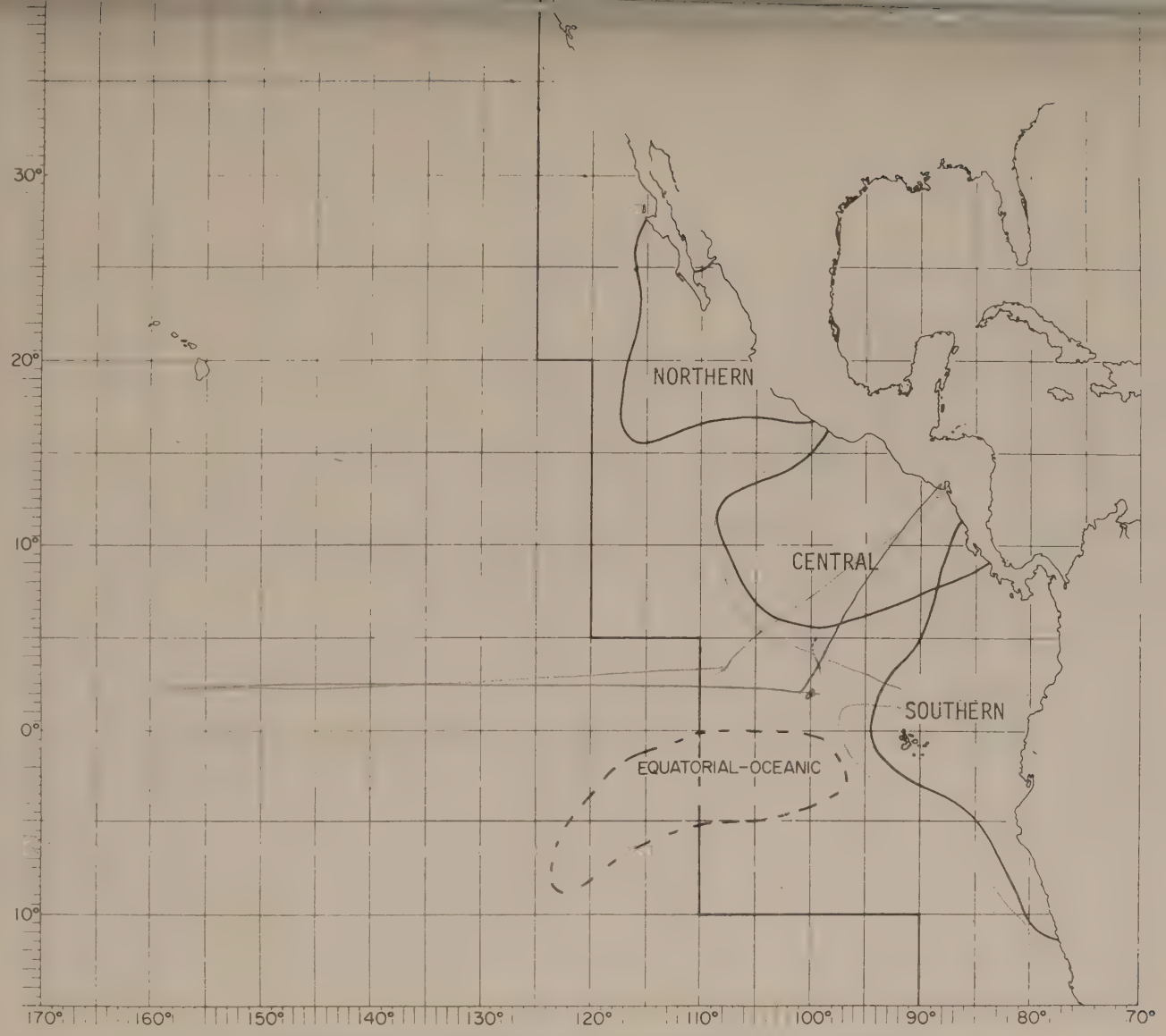
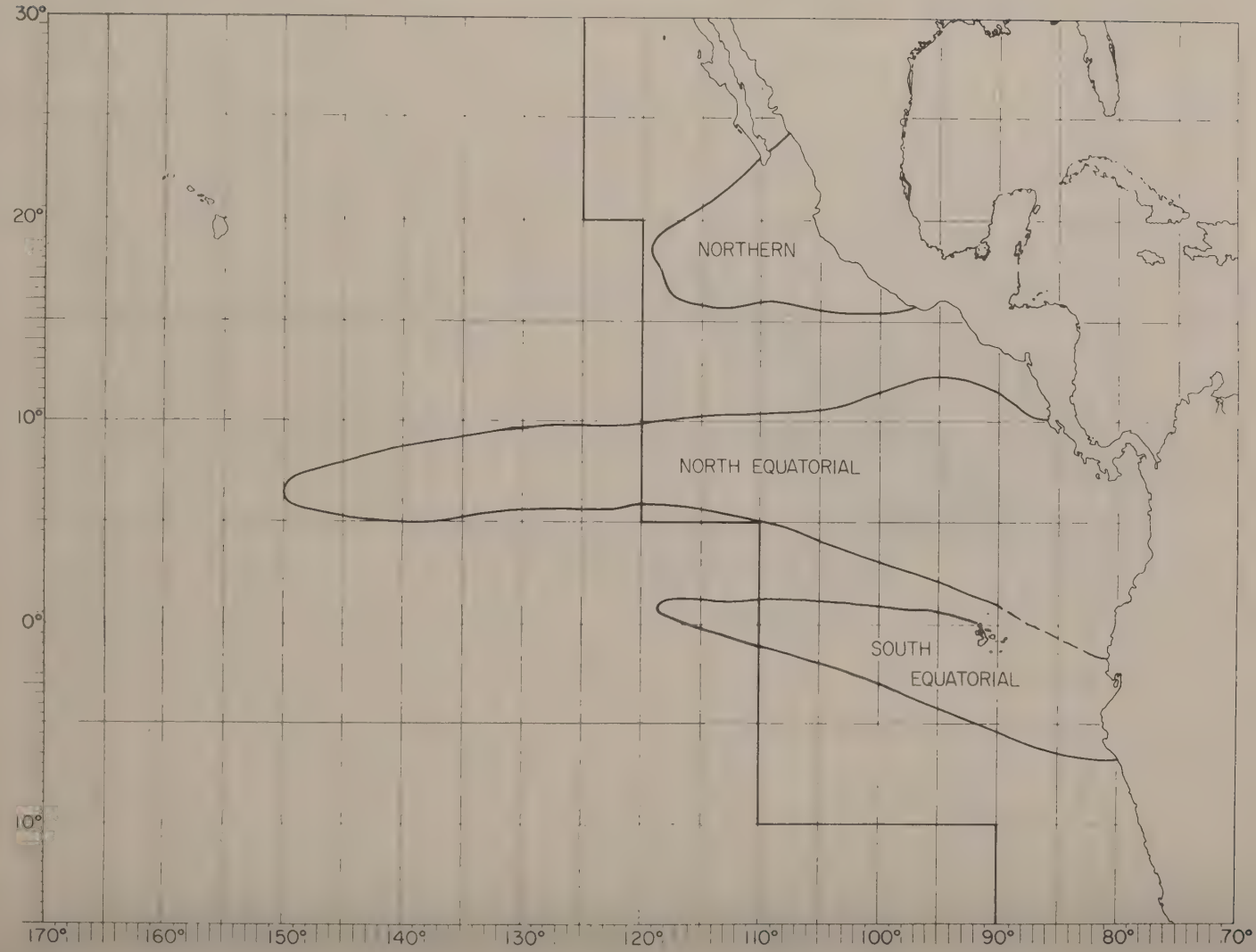


Figure 5. Geographical distributions of common dolphin stocks in the eastern tropical Pacific (PSA/15)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APPENDICES TO THE

REPORT OF THE WORKSHOP ON STOCK ASSESSMENT OF PORPOISES INVOLVED IN THE EASTERN PACIFIC YELLOWFIN TUNA FISHERY

SOUTHWEST FISHERIES CENTER ADMINISTRATIVE REPORT

NO. LJ-76-29

APPENDIX 1

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APPENDIX 2

WORKSHOP ON THE STOCK ASSESSMENT OF EASTERN PACIFIC PORPOISES INVOLVED IN THE YELLOWFIN TUNA FISHERY

AGENDA

1. Introduction

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5. Estimation of optimum sustainable population levels

6. Impact of levels of fishing mortality on existing and optimum sustainable population levels

7. Preparation of report

APPENDIX 3

LIST OF WORKSHOP DOCUMENTS

PSA/1. SWFC. 1975. Progress of research on porpoise mortality incidental to tuna purse-seine fishing for fiscal year 1975. SWFC Admin. Rept. No. LJ-75-68.

PSA/2. Richey, Charles R. 1976. C.A. No. 74-1465 and C.A. No. 75-0227, Memorandum of opinion. U.S. District Court, District of Columbia, May 11, 1976.

PSA/3. Marine Mammal Protection Act of 1972. Public Law 92-522.

PSA/4. Kimura, M., and William F. Perrin. Progress report on studies of the biology of the striped dolphin, Stenella coeruleoalba, in the eastern tropical Pacific. SWFC Admin. Rept. No. LJ-76-11.

PSA/5. Perrin, William F, James M. Coe and James R. Zweifel. Growth and reproduction of the spotted porpoise, Stenella attenuata, in the offshore eastern tropical Pacific. Fish. Bull. 74(2). [In press]

PSA/6. Perrin, William F, David B. Holts and Ruth B. Miller. Preliminary estimates of some parameters of growth and reproduction of the whitebelly spinner dolphin, a geographical form of Stenella longirostris, in the eastern tropical Pacific. SWFC Admin. Rept. No. LJ-76-12.

PSA/7. Perrin, William F., David B. Holts and Ruth B. Miller Growth and reproduction of the eastern spinner dolphin, a geographical form of Stenella longirostris in the eastern tropical Pacific. SWFC Admin. Rept. No. LJ-76-13.

PSA/8. Powers, Joseph E. 1976. Estimated incidental porpoise mortality in the eastern Pacific tuna fishery for 1975. SWFC Admin. Rept. No. LJ-76-4.

PSA/9. Smith, Tim D. 1975. Estimates of sizes of two populations of porpoise (Stenella) in the eastern tropical Pacific Ocean. SWFC Admin. Rept. No. LJ-75-67.

PSA/10. Fox, W.W., Jr., J.E. Powers, and D.W.K. Au. 1976. A working paper on the definition of optimum sustainable population.

PSA/11. Perrin, William F., Ruth B. Miller, and Priscilla A. Sloan. 1976. Reproductive parameters of the offshore spotted dolphin, a geographical form of Stenella attenuata, in the eastern tropical Pacific, 1973-1975.

PSA/12. Perrin, William F. 1975. Distribution and differentiation of populations of dolphins of the genus Stenella in the eastern tropical Pacific, J. Fish. Res. Bd. Can. 32(7): 1059-1067.

PSA/13. Anon. 1976. Published works of the SWFC Marine Mammal Program since January 1968.

PSA/14. Smith, T. 1976. Current understanding of the status of the porpoise populations in the Black Sea. FAO Sci. Cons. Mar. Mammals. ACMRR/MM/SC/40. 11p.

PSA/15. Evans, W.E. 1976. Distribution and differentiation of stocks of Delphinus delphis Linnaeus in the northeastern Pacific. FAO Sci. Cons. Mar. Mammals. ACMRR/MM/SC/18. 72p.

PSA/16. Kasuya, T. and N. Miyazaki. 1975. The stock of Stenella coeruleoalba off the Pacific coast of Japan. FAO Sci. Cons. Mar. Mammals. ACMRR/MM/EC/25.

PSA/17. Miyazaki, N. 1976. School structure of Stenella coeruleoalba. IWC Small Cet. Subcomm. Working Doc. No. L.18. 6p.

PSA/18. Kasuya, T., N. Miyazaki, and W.H. Dawbin. 1974. Growth and reproduction of Stenella attenuata in the Pacific coast of Japan. Sci. Rept. Whales Res. Inst. 26: 157-226.

PSA/19. Perrin, W.F. 1974. Mortality. Unpublished manuscript. 12p.

PSA/20. Brown, W. 1976. Optimum sustainable population.

PSA/21. Bertrand, G. 1976. Letter to William Fox, July 26, 1976.

PSA/22. Perrin, W. 1976. List of cetaceans killed incidentally by U.S. tuna purse seiners in the eastern Pacific.

PSA/23. Au, D.W.K. 1976. Porpoise distribution charts.

PSA/24. MMC 1976 Optimum.

PSA/25. Eisenbud, R. 1976. Memorandum on optimum sustainable population levels, July 13, 1976.

PSA/26. Anon. 1976. Summary of the draft report of workshops on conservation of wild living resources.

PSA/27. Holt, Sidney J., and Lee M. Talbot (ed.). 1975. The conservation of wild living resources. Draft report of Airlie House Workshops, Council of Environmental Quality, Wash., D.C., 55p.

APPENDIX 4

DATA AND METHODOLOGY ASSUMPTIONS

Introduction

The various estimates are, as in all statistical calculations, subject to error, which is acknowledged in the expressions of variance and in the established confidence intervals. The estimates also depend on a number of assumptions. The possible failure of these assumptions is considered and reviewed in this appendix. This review is organized around the major data inputs.

I. Existing populations

The methodology of estimating population size is described in Appendix 5. The three major data inputs are density of schools, school size, and geographical range.

A. Density of schools was estimated two ways, by aerial survey and from sighting data collected by observers aboard commercial tuna seiners.

1. It is assumed that the exponential model used for the decline in probability of sighting with distance from the track line is valid. Further, it is assumed that the probability of sighting a

school on the track line is unity. If some schools on the track line are missed, then the estimates of density (number of schools per unit area) and population sizes are biased downward. If the exponential model is not valid, it is likely that the density is overestimated according to studies of this situation.

2. It is assumed that searching effort by tuna seiners is approximately randomly distributed within the sample strata with respect to the porpoise schools. If because of the communication between vessels and the attempt to encounter as many tuna/porpoise schools as possible, this is not true, then the estimates of school density and the population estimates based on tunaboat observer data alone are overestimates. However, the use of aerial tracks may correct for this source of non-randomness of searching, because the aircraft travelled along predetermined paths and did not seek porpoise schools on the basis of information obtained by radio.

3. It is assumed that school sightings are independent and unique events. If schools were resighted by tunaboats as a direct result of course changes occasioned by the initial sightings, as for example in a zig-zag searching pattern, then the school density estimates by tuna vessels alone are overestimates. However, as much care as possible was taken to delete data derived from such zig-zag search patterns.

4. It is assumed that the estimated radial sighting distance aboard the tunaboats is the distance at which the existence of the porpoise/bird aggregation is recognized by the vessel and appropriate course change must be made if the aggregation is to be checked for presence of tuna. Birds can be sighted above the horizon, at a greater distance than can porpoise. If, as in the 1975 and 1976 tunaboat data, the distance noted is that distance at which the porpoise themselves were sighted (sometime after sighting of the birds and after a course change toward the birds), then the effective path width would be underestimated and density of schools would be therefore overestimated. However, because the distribution of sighting angles in the 1974 tunaboat data closely approximated the distribution of angles to be expected if sighting distance were recorded before course change toward birds, the mean sighting distance for that year was used as the standard for all years (see Appendix 5). Additional support for use of the 1974 path width is that the 1974 path width was approximated on two marine mammal surveys conducted from research vessels in 1976, in which sightings were noted when first made, whether by means of birds or porpoise. These cruises, however, may not be directly comparable to commercial tunaboat cruises because crew members of the tunaboats are more experienced and are presumed to be more proficient in sighting distant bird flocks than are observers on research cruises. To the degree (undetermined) to which the 1974 sighting distance was affected by the porpoise-vs-bird problem, the shipboard school density estimates alone are overestimates.

5. It is assumed that the distances and angles estimated to the school at the time of first sighting are without bias, whether from the airplane or from tunaboats.

B. School size was estimated by crewmen aboard the tunaboats carrying observers.

1. It is assumed that there is no systematic error up or down in estimating school size. Sparse data indicate that biological observers in the field tend to underestimate the size of large porpoise schools, but that tuna fishermen may tend to overestimate school size. This problem has led to plans for field research to calibrate crew estimates photographically. If crew estimates of school size are indeed overestimates, then the population sizes are overestimated based on observations from commercial tunaboats. However, school size estimates from the aerial survey for offshore spotted dolphins and eastern spinner dolphin were for the most part not statistically different from the ship survey estimates in 1974.

2. It is assumed that school size is the same in unsurveyed portions of the range as in surveyed portions. For the spotted dolphin, for example, average school size was assumed to be the same in the unsurveyed far-offshore half of the range as in the surveyed more inshore half. If schools were larger to the west, then the population estimate is an underestimate, if they were smaller, it is an overestimate.

C. Range was estimated by various means for the different stocks.

1. It was assumed that the area of overlap of the eastern and whitebelly spinner stocks of the spinner dolphin is symmetrical in terms of density, and half of the overlap was therefore allotted to each stock. If the change in density is not symmetrical, the population of one stock is overestimated and that of the other stock underestimated. Because juvenile color patterns are the same in both forms and resemble that of the adult whitebelly spinner, the eastern form is more likely to be misidentified as whitebelly spinner than the reverse. If this is true, it may cause overestimation of the range (and population sizes) of the whitebelly spinner stock and underestimation for the eastern stock.

2. The extent of the total historical geographical ranges are imprecisely known for some stocks. If the range occupied at the time of a survey was larger than the (known total) range used to expand the density estimates, then that population estimate is an underestimate.

3. Most of these porpoise are warm-water species that are closely associated with waters characterized by a shallow thermocline overlying a gradient of rapidly decreasing oxygen content. The area occupied by many of these species may be limited to the south by incursions of cold water from the Humboldt Current and to the north by the cooler waters associated with the California Current and the area off Baja California. A long tongue of warm water extending westward is

centered approximately along 10°N latitude, and many of these species (e.g., *Stenella attenuata*, the spotted dolphin, and *S. longirostris*, the spinner dolphin) live in these waters. Other species (e.g., *Delphinus*, the common dolphin) are characteristic of cooler waters, although not confined to them, and the relation between their distributions and the environment may be more complex. Generally, the ranges of the porpoise species have been determined on the basis of all sightings and samples obtained over a number of years. Because for at least some of these species (e.g., the spotted and the spinner dolphins) the distributions may well vary from time to time with the fluctuations in the general oceanographic environment, e.g., occurrences of El Niño to the south of the known ranges, the area occupied at any one time, may not be exactly coincidental with that of the whole historical range. In this case the use of the known range to estimate the total population size could result in an overestimate.

4. In population estimates derived by expansion of densities into areas little surveyed, as in the farther portions of species ranges, expected decline in density toward the boundaries are assumed to be compensated for by higher densities in other oceanographically favorable regions of the range such that densities from the surveyed areas are applicable in the expansion. If there is overall decline in density toward the boundaries, then the population sizes are overestimated. The opposite may be true if the density increases towards one or more of the boundaries.

II. Incidental Kill

Incidental kill was estimated from kill rate data collected by NMFS observers and total net set data provided by IATTC (Appendix 6).

A. Kill rate

1. The sample includes very few kill rate data from the area to the west of the CYRA (a major portion of range of the spotted dolphin and whitebelly spinner dolphin); it is assumed that the rates are the same outside as inside the CYRA. Higher or lower kill rates would result in under- or overestimates.

2. The kill rate estimates include only observed kill. If fishery-related deaths occur after porpoise have been released from the seine, due to internal injuries, separation of nursing calf from mother, increased vulnerability to predators because of social disruption, or other factors, then the fishing mortality is underestimated. It is noted that beginning in 1975 NMFS observers began to record serious injury as well as actual mortalities. These have not been included in any of the analyses made in this Workshop.

3. It is assumed that there is no "observer effect" on fishing mortality; i.e., that kill rates on vessels without NMFS observers are the same as on those with observers. If rates are higher on

vessels without observers, then fishing mortality is underestimated. This consideration is particularly important in view of the change in emphasis of the observer program from research until mid-1975 to management and enforcement from 1976 onwards.

B. Total net sets

1. Early IATTC logbook records contain relatively fewer sets which are differentiated as porpoise sets and non-porpoise sets. The number of porpoise sets, and hence, fishing mortality may be underestimated or overestimated for the early years.

2. It is assumed that net sets on porpoise reported to the IATTC are a random sample of all sets on porpoise. If some sets on porpoise are reported as sets on schoolfish or fish associated with floating objects, or relatively more frequently as unidentified, then fishing mortality is underestimated. However, independent estimates for 1974, 1975, and 1976 indicate no significant discrepancies occurred in those years. For earlier years there were no reasons for under-reporting to occur.

3. It is assumed that set locations are correctly reported. For example, if some sets are reported incorrectly on the geographical scale of the differential ranges of the two spinner stocks, then fishing mortality may be underestimated for one stock and overestimated for the other.

III. Reproductive parameters

A. Samples are presently taken as and when the fishing operations make them possible. This type of sampling is well known in other fisheries and usually leads to very much-less-than-ideal data for size frequencies and for all parameters related to size, e.g., reproduction parameters. Gross reproduction rate has been estimated partly from a knowledge of the length of the calving cycle. This in turn depends upon knowledge of the duration of the lactation and resting periods. Lack of adequately randomized and stratified samples could affect knowledge of the size at weaning, pregnancy rate, and some other reproduction parameters involved in the back calculations of population size.

B. Gross reproductive rate has been calculated from the number of calves recruited to the population. The number of recruits to the sexually mature adult population has not been calculated. If increased production of calves did not effect or only partially increased the number of recruits entering the sexually mature female population, then gross reproductive rate may overestimate the net reproductive rate. On the other hand, the gross reproductive rate of presumably unfished stock was used for an estimate of natural mortality rather than the lower estimate of total mortality of adult females. To the extent that this stock is fished or to the extent that gross reproduction exceeds natural mortality, the net reproductive rate is underestimated.

APPENDIX 5

ESTIMATION OF SIZES OF EXISTING PORPOISE POPULATIONS

Stock assessment relies upon estimates (or indices) of the abundance of animals in the stock. Therefore in order to determine the impact of incidental mortality on porpoise stocks in the eastern tropical Pacific, the sizes of the existing populations must be calculated. The following methodology, calculations and estimates were derived by the workshop group for the affected stocks. Several procedures and adjustments were employed to produce what the group thought to be the best estimates, given the available data. This appendix reviews the sources of the data, the theory of the estimation model, the assumptions of the model, the procedures to attempt to more closely adhere to the assumptions, and the resulting estimates. Peculiarities of the methodology associated with each stock are given in order to present a complete synopsis of the estimation procedures.

1. Data Sources

The porpoise population sizes were estimated using data from an aerial survey conducted in 1974 (PSA/9) and from shipboard surveys in 1974, 1975, and 1976. The shipboard surveys were conducted aboard vessels of the United States yellowfin tuna purse seine fleet while they were under normal operating conditions. During these surveys, the frequency of observations of porpoise schools was recorded, as

was the species composition of the school, the school size, the distance from the observer to the school when it was sighted, and the angle from the vessel's (airplane's) heading to the school when the school was sighted. Also, the distance that the vessel (airplane) searched was recorded.

II. Model

The data so obtained were used to estimate the density of schools using line transect procedures i.e.,

$$\hat{D} = \frac{n-1}{2\,L\,W} \qquad (1)$$

where $\hat{D}$ is the density of the schools, N is the number of sightings of schools, L is the linear distance searched (track length) and W is the measure of the width of the searching path. When sightings fall off in an exponential fashion with sighting distance, the arithmetic mean of the perpendicular sighting distance is the appropriate estimator of W. The perpendicular distance was used for the 1974 aerial and shipboard survey analyses (PSA/9), and its use was continued herein.

The school density [equation (1)] was expanded to population size by multiplying the average number per school and by the area of the population's geographical range.

III. Assumptions

The assumptions of (1) are discussed fully in PSA/9 and general assumptions are discussed in Appendix 4. Perhaps the two most critical of these assumptions are that of randomness of search of purse seiners relative to porpoise and the use of mean perpendicular sighting distance as the measure of search width.

Biases in the shipboard survey relative to the aerial survey were recognized and adjusted for by means of a ratio correction. This ratio was the population estimate derived from the aerial survey in 1974 divided by the estimate derived from the Jan.-Feb., 1974 shipboard data (PSA/9)

The effective path search width for the 1974 shipboard survey was reported in PSA/9 to be 1.98 nautical miles (nm) of perpendicular distance. For 1975 this decreased to 1.39 nm and further to 0.92 in 1976. Since results from scientific survey cruises of early 1976 showed average perpendicular sighting distances to be in the order of 2 nm, differential bias in the measurement of distance from the tuna vessel was indicated. Further investigation into the observer records and the instructions for keeping the records show there may have been confusion in 1975 and 1976 as to whether the distance was recorded when the porpoise school was sighted or when birds above the porpoise school were sighted. Birds are often the first indicator

of a porpoise school and they are actively sought by the searching tuna fishermen. Clearly, the distance when the birds are sighted is a better measure of path width. In 1976 when the radial distance from vessel to porpoise school and vessel to birds was recorded for sights upon which sets were made, the birds were sighted on an average of 0.99 nm further away. Also, the sighting angles from the shipboard surveys were distributed as follows:

Angle (degrees)	Expected percentage of sightings	Observed percentages of sightings 1974	1975	1976
0-30	50	46	66	70
30-60	37	36	23	21
60-90	13	18	11	9

The 1974 distribution is close to that expected, while 1975 and 1976 become progressively skewed toward lower sighting angles. For these reasons, the shipboard estimates of school density in 1975 and 1976 were adjusted by the ratio of the perpendicular distance of the particular year to that of 1974. The ratio was, then, 1.39/1.98 for 1975 and 0.92/1.98 for 1976.

IV. Time-Area Stratification

In PSA/9 the survey area was partioned as in Fig. 1 on the basis of the area of the 1974 shipboard and aerial surveys and on the range of known sightings of offshore spotted dolphin and eastern spinner dolphin as of 1973. Time stratifications were chosen as early season

(Jan.-Feb.) and late season (March-June) to correspond to times of historically more and less intense porpoise fishing, respectively.

Since the range of known sightings of spotted and eastern spinner dolphins was extended with data derived from 1974-1976, the grid system of Fig. 1 was expanded as in Fig. 2. The expanded grid system includes areas whose outer boundaries are defined according to the particular stock being discussed.

V. Results

Sightings of porpoise schools and associated information in 1975 and 1976 stratified by area are given in Tables 1 and 2. The same data for 1974 are given in PSA/9. Sightings for the expanded grid system are given in Tables 3-6. Comparable data for the aerial survey of 1974 and shipboard surveys of 1974, 1975 and 1976 are only available for the early season (Jan.-Feb.), therefore only these data are included.

Density estimates for each area were computed for the pooled sightings of spotted, eastern spinner, whitebelly spinner and unidentified spinner dolphin, and separately for the pooled sightings of common dolphin, striped dolphin, "other porpoise", and unidentified porpoise using equation (1). These estimates were separated to species and stock by the frequency of occurrence. Unidentified spinners and unidentified porpoise were also prorated to species and

stock by frequency of occurrence. It was assumed that unidentified porpoise only included common dolphin, striped dolphin, and other (non-spotted and non-spinner) porpoise for purposes of prorating. The density estimates by area are given in Tables 7 and 8 for the unexpanded grid system and expanded grid system, respectively.

Average number of porpoise per school are given in Table 9. These were used to expand school abundance to population abundance. The exact procedures for estimating abundance for each species and/or stock depend upon the population examined. Therefore, the following is the stock by stock discussion of the abundance estimation methods and results.

A. Offshore Spotted Dolphin

An average density of spotted dolphin schools weighted by the relative area of each geographical stratification to the total area was computed for early season ship survey for 1975 and 1976 using Fig. 1 and Table 7. The 1974 density using the same procedure is given in PSA/9. The 1975 and 1976 estimates were corrected for differential bias of the sighting distances by the ratios of 1.39/1.98 and 0.92/1.98, respectively. These estimates were expanded by school sizes (Table 9) and the range of spotted dolphin as known in 1973 (2.6 million nm^2) yielding:

	Population Size
1974	3.9 million
1975	4.9 million
1976	3.4 million

with a mean of 4.04 million. The best estimate derived solely from the 1974 shipboard survey (PSA/9) was 3.5 million. However, this was taken from data from both early and late season, i.e., from January to June. In order to correct for seasonality, the population size of 4.04 million was multiplied by the ratio of 3.5 million and the early season 1974 shipboard estimate of 3.85 which gives 3.67 million.

The above estimation was based upon the geograhpical range known in 1973. Using the extended range of approximately 3.3 million nm^2 and the expanded grid system (Tables 8 and 9, Fig. 2), new weighted averages for 1975 and 1976 were calculated and corrected for differential bias in sighting distance. The 1974 abundance using the expanded geographical range was computed by multiplying the 1974 unexpanded estimate (3.9 million) by the ratio of the sum of the estimated abundances in 1975 and 1976 using the expanded range to the sum of 1975 and 1976 estimates using the smaller range (2.6 million nm^2), i.e., 1.11. These calculations yielded:

1974	4.3 million
1975	5.0 million
1976	4.4 million

and a mean of 4.56 million. The shipboard estimate of 3.67 million for the known range as of 1973 was then adjusted to the expanded range by multiplying the ratio of the mean expanded estimate (4.56) and the mean unexpanded estimate (4.04). This resulted in an estimate of 4.14 million.

The participants choice of the best estimate of spotted dolphin abundance from the 1974 aerial survey was 3.3 million (2.3 to 4.2 million) derived by Chapman's[1] handling of the data in PSA/9. This estimate assumed a geographical range of 2.6 million nm^2. The 3.3 million estimate was adjusted for the expanded range (3.3 million nm^2) by multiplying by the ratio of the mean expanded shipboard estimate (4.56) and the mean unexpanded shipboard estimate (4.04) yielding 3.7 million animals (2.6 to 4.7 million).

The estimates produced may be summarized

	Estimates	Approximate Confidence Intervals
1974 aerial survey with 1973 range	3.3 million	(2.3 to 4.2 million)
1974 aerial survey with expanded range	3.7 million	(2.6 to 4.7 million)
1974-1976 shipboard survey with 1973 range	3.7 million	
1974-1976 shipboard survey with expanded range	4.1 million	

The four results are within the approximate 95% confidence limits of either aerial survey estimate. The group recognized that the four were not likely to be significantly different from one another. Also, as discussed in Appendix 4 and in this appendix, there are likely to

[1] Dr. Douglas Chapman, College of Fisheries, University of Washington, Seattle. "Review of Estimated Impact of Tuna Purse Seine Fishery in Eastern Tropical Pacific on Porpoise Population," October 1975.

be more inherent biases associated with the shipboard surveys. The aerial survey fit the estimation model more fully. For these reasons, the group preferred the aerial estimates. However, not being able to choose between the expanded range estimate and that using the 1973 range, the group decided to average the two, i.e., 3.3 million and 3.7 million were averaged to give 3.5 million. The size of the offshore spotted dolphin population as of Jan. 1, 1974 was then taken to be 3.5 million animals with approximate 95 percent confidence limits of 2.5 to 4.5 million.

B. Eastern Spinner Dolphin

Several estimates of eastern spinner dolphin abundance were made from the data procured from 1974 aerial survey (PSA/9). Chapman[2] derived an estimate of 1.15 million (0.75 to 1.55 million) from this data based upon a range of 1.2 million nm^2 for eastern spinner dolphin. The group agreed that this was the best estimate to be derived from the aerial survey with the unexpanded (1973) range.

The 1974 shipboard survey data (PSA/9) did not include records of a substantial number of whitebelly spinner sightings. Therefore, unidentified spinners were classified as eastern spinners and their geographical range was reduced in order to compensate (PSA/9). A much larger number of spinner dolphin were classified in both the whitebelly spinner and unidentified spinner categories from the shipboard surveys of 1975 and 1976. Therefore, these years were considered exclusively.

[2]See Footnote 1.

The average density of all spinners was computed (weighted by the relative area) for the unexpanded grid (Tables 1and 2, and Fig. 1). The density was corrected for sighting distance bias and expanded by school size of eastern spinner dolphin (Table 9) and by the range of all spinners (2.6 million nm^2). Then the abundance of eastern spinner was found by prorating according to the percent of sightings in Tables 1 and 2. The results were

1975	1.7 million
1976	0.9 million

with a mean of 1.28 million.

The same procedure was used for the expanded range (3.3 million nm^2) using Tables 3 and 4, and Fig. 2, giving

1975	1.4 million
1976	1.2 million

with a mean of 1.33 million. The ratio of the mean for the expanded range (1.28) was multiplied by the preferred estimate from the unexpanded aerial survey to give

$$1.15 \times 1.33/1.28 = 1.20 \text{ million.}$$

Therefore, the estimate for the expanded range is not significantly different from the unexpanded (1.20 to 1.15).

As discussed before, the shipboard surveys suffer from lack of fit to the estimation model. Therefore the group chose again to rely upon the results from the aerial survey. The estimates for the expanded and unexpanded ranges were averaged and rounded to one decimal. Therefore, the group based its further stock assessment work upon a best estimate of the abundance of eastern-spinner dolphin of 1.2 million (0.8 to 1.6 million) as of Jan. 1, 1974.

C. Whitebelly Spinner Dolphin

Very little of the searching effort of either the shipboard or aerial surveys was conducted within the geographical range of the whitebelly spinner dolphin. Therefore, extrapolating density to the unsearched areas is especially tenuous. However, some observations were made in 1976 on the whole range of the whitebelly spinner, and these were analyzed to obtain population estimates below.

This method uses the comparison of sightings of spinner and spotted dolphin from two vessels which have recently (June, 1976) returned from fishing outside the IATTC regulatory area, the primary region of whitebelly spinner abundance. For these two cruises 87,902 spotted dolphin and 14,900 spinner dolphin were sighted. All spinners were assumed to be whitebelly spinners suggesting that whitebelly spinner population density is 16.95% (14900/87902) of spotted dolphin

density. The best estimate of spotted dolphin abundance was 3.5 million. Using the unexpanded range, whitebelly spinners occupy 61.54% of the total range of 2.6 million nm^2. Therefore, the product of (.6154)x(3.5)x(.1695) is 0.37 million whitebelly spinner dolphin. Using the expanded range, 75.67% of the total range of 3.3 million nm^2 is occupied by whitebelly spinners and the product is (0.7576)x (3.5)x(0.1695) or 0.45 million whitebelly spinner dolphins.

The group chose an intermediate value of 0.4 million with approximate 95% confidence limits of 0.29 to 0.51 million (derived from the standard error of the offshore spotted dolphin estimate times the appropriate ratio) as its best estimate of the abundance of whitebelly spinner dolphin as of Jan. 1, 1974.

D. Common Dolphin

For purposes of this analysis the common dolphin were broken into three stocks: northern, central and southern stocks, corresponding to the description of the Mexican short-snout stock, the Costa Rican short-snout stock, and the Galapagos short-snout stock, respectively in PSA/15. It was assumed that the northern stock only occurred in the far north nearshore, far north offshore, north nearshore, north midshore, and north offshore sections of the grid in Fig. 2 and Table 8. The central near-, mid-, and offshore sections were assumed to only

contain the central stock, and the southern near-, mid-, and offshore sections as well as the far south nearshore section were assumed to only encompass the southern common dolphin stock.

The geographical ranges of the northern, central, and southern stocks were estimated to be 0.383, 0.612, and 0.675 million nm^2, respectively. Using Tables 5 and 6, an estimation of density from pooled sightings was calculated from equation (1) for each appropriate common dolphin stock. The average perpendicular sighting distance used for all estimates was 0.90 nm in 1975 and 0.91 nm in 1976. These are the mean sighting distances for all sightings of non-spotted and non-spinner dolphin in the two years. The pooled density was corrected for sighting distance bias, aerial-shipboard bias, and seasonality for each stock, expanded by school size and the geograhpical range to yield:

Northern	1975	0.46 million
	1976	0.33 million
Central	1975	0.27 million
	1976	0.18 million
Southern	1975	0.75 million
	1976	0.84 million

The average population sizes of the three stocks listed from north to south (with approximate 95% confidence limits) are 0.40, (0.31 to 0.49), 0.23 (0.10 to 0.36), and 0.80 million (0.67 to 0.93), respectively with a total common dolphin estimate of 1.43 million.

E. Striped Dolphin

Estimation of population abundance of striped dolphin was made on the basis of two stocks, the northern and the north equatorial, which occupy approximately 0.383 and 1.845 million nm^2, respectively. It was assumed that the north stock is contained in the northern sections of the grid (Fig. 2, Table 8), whereas the north equatorial stock occupies the central and southern sections of the grid (Fig. 2, Table 8). Pooled sightings were used to estimate density for each stock by equation (1) and Tables 5 and 6. These coupled with the appropriate school sizes (Table 9) and ranges resulted in

Northern	1975	9000
	1976	28000
North Equatorial	1975	72000
	1976	390000

These estimates were corrected for bias of shipboard surveys relative to the aerial survey, but they were not corrected for bias of sighting distance. This was because the bias assumed to operate in this case is relative to the active searching for porpoise schools associated with yellowfin tuna. Striped dolphin schools do not usually associate with tuna, thus it was assumed that biases between the years are less applicable.

The year to year variations were caused by changes in the estimate of average school size between 1975 and 1976 (Table 9). Both sample sizes are relatively small and the result is a large variation in population size.

Using the above, the best estimate of abundance of the northern stock is the mean of 18,000 animals (2,000 to 34,000) and for the north equatorial stock the mean of 230,000 animals (110,000 to 350,000). The total estimated number of striped dolphin is 248,000.

F. Bottlenosed Dolphin, Rough-toothed Dolphin, Fraser's Dolphin, Pacific White-Sided Dolphin, Risso's Dolphin and Pilot Whale

The distribution and stock structure of these six species in the eastern tropical Pacific are relatively unknown. The group decided that the best that could be done was to calculate the relative number of sightings of each species to offshore spotted dolphin within the range of the fishery. The number of individual sightings for the seven species are given in Table 10 along with the sighting index relative to the offshore spotted dolphin.

VIII. Conclusion

The estimates of porpoise abundance made herein are based primarily on line transect methods and are subject to the assumptions

of the theory. Discussion of possible failures of the assumptions and resulting biases are given in Appendix 4.

In this appendix failures of the assumptions have been further considered and some adjustments made for them. The data are less than desirable, particularly so for the secondary species, but the participants believe that the estimates and recommendations are the best that can be made at this time.

Table 1. Sighting and searching effort during shipboard survey of Jan-Feb, 1975. Areas are those used in PSA/9, and in Fig. 1.

Section	Track Miles (nm)	Perp. Sighting Dist. (nm)	School Sightings (Number)							
			Spotted		East. Spinner		White. Spin.		Unid. Spin.	
			Pure	Mixed	Pure	Mixed	Pure	Mixed	Pure	Mixed
North Nearshore	6678	1.66	8	2	0	0	1	0	1	2
Cent. Nearshore	10551	1.66	103	178	11	88	1	1	14	89
South. Nearshore	1454	0.45	5	0	0	0	1	0	3	0
North Midshore	1920	1.24	19	2	0	0	0	1	0	1
Cent. Midshore	14345	1.55	83	30	0	11	2	3	3	16
South Midshore	2672	1.52	8	1	0	0	0	0	1	1
North Offshore	1568	2.41	8	5	0	2	0	0	1	3
Cent. Offshore	22674	1.60	107	126	3	23	5	49	5	54
South Offshore	2731	1.25	15	4	0	1	0	1	0	2

Table 2. Sighting and searching effort during shipboard survey of Jan-Feb, 1976. Areas are those used in PSA/9, as in Fig. 1.

Section	Track Miles (nm)	Perp. Sighting Dist. (nm)	School Sightings (No.)							
			Spotted		East. Spin.		White. Spin.		Unid. Spin.	
			Pure	Mixed	Pure	Mixed	Pure	Mixed	Pure	Mixed
North Nearshore	1825	1.14	4	1	0	0	0	0	0	1
Central Nearshore	7442	0.79	61	38	5	13	0	1	9	24
South Nearshore	2351	0.44	2	1	0	0	0	0	0	1
North Midshore	753	0.74	4	0	0	0	0	0	0	0
Cent. Midshore	2864	1.73	16	4	0	2	1	0	2	2
South Midshore	2812	0.75	3	7	0	3	0	1	0	3
North Offshore	690	0.42	3	1	1	0	0	0	0	1
Central Offshore	2334	0.48	4	6	1	1	0	3	3	2
South Offshore	6448	1.11	42	20	0	3	2	12	0	5

Table 3. Sighting and searching effort during shipboard survey of Jan-Feb, 1975 for expanded grid areas. The expanded grid is given in Fig. 2.

Section	Track Miles (nm)	Perp. Sightings Dist. (nm)	School Sightings (No.)							
			Spotted		East. Spin.		White. Spin.		Unid. Spin.	
			Pure	Mixed	Pure	Mixed	Pure	Mixed	Pure	Mixed
Far North Nearshore	3135	0.96	4	1	0	0	0	0	0	1
Far North Offshore	2427	0.10	0	0	1	0	0	0	0	0
North Nearshore	6678	1.66	8	2	0	0	1	0	1	2
Central Nearshore	10551	1.66	103	178	11	88	1	1	14	89
South Nearshore	1454	0.45	5	0	0	0	1	0	3	0
North Midshore	1920	1.24	19	2	0	0	0	1	0	1
Central Midshore	14345	1.55	83	30	0	11	2	3	3	16
South Midshore	2672	1.52	8	1	0	0	0	0	1	1
Expanded North Offshore	1568	2.41	8	5	0	2	0	0	1	3
Expanded Central Offshore	22983	1.60	107	130	3	23	5	52	5	55
Expanded South Offshore	4591	1.25	20	6	0	1	0	1	0	4
Far South Nearshore	2100	-	0	0	0	0	0	0	0	0

Table 4. Sighting and searching effort during shipboard survey of Jan-Feb, 1976 for expanded grid areas. The expanded grid is given in Fig. 2.

Section	Track Miles (nm)	Perp. Sightings Dist. (nm)	School Sightings (No.)							
			Spotted		East. Spin.		White. Spin.		Unid. Spin.	
			Pure	Mixed	Pure	Mixed	Pure	Mixed	Pure	Mixed
Far North Nearshore	2887	1.18	1	2	0	0	0	0	0	2
Far North Offshore	1016	-	0	0	0	0	0	0	0	0
North Nearshore	1825	1.14	4	1	0	0	0	0	0	1
Central Nearshore	7442	0.79	61	38	5	13	0	1	9	24
South Nearshore	2351	0.44	2	1	0	0	0	0	0	1
North Midshore	753	1.69	4	0	0	0	0	0	0	0
Central Midshore	2864	1.73	16	4	0	2	1	0	2	2
South Midshore	2812	0.75	3	7	0	3	0	1	0	3
Expanded North Offshore	690	0.42	3	1	1	0	0	0	0	1
Expanded Central Offshore	2802	0.48	4	8	1	1	0	4	3	3
Expanded South Offshore	25310	1.11	62	67	0	4	8	48	6	15
Far South Nearshore	1487	-	0	0	0	0	0	0	0	0

Table 5. Sighting and searching effort during shipboard survey of Jan-Feb, 1975 for expanded grid areas. The expanded grid is given in Fig. 2.

Section	Track Miles (nm)	Perp. Sighting Dist. (nm)	Common Dolphin	Striped Dolphin	Other Porpoise	Unidentified Porpoise
Far North Nearshore	3135	0.64	27	0	9	16
Far North Offshore	2427	0.48	15	0	7	4
North Nearshore	6678	1.20	9	1	7	42
Central Nearshore	10551	1.23	13	1	89	54
South Nearshore	1454	0.68	9	0	9	5
North Midshore	1920	1.29	3	1	0	10
Central Midshore	14345	1.39	35	3	40	58
South Midshore	2672	0.56	4	1	5	11
Expanded North Offshore	1568	1.32	4	0	1	1
Expanded Central Offshore	22983	0.97	19	6	3	65
Expanded South Offshore	4591	0.85	16	1	7	22
Far South Nearshore	2100	1.05	7	0	4	22

Table 6. Sighting and searching effort during shipboard survey of Jan-Feb, 1976 for expanded grid areas. The expanded grid is given in Fig. 2.

Section	Track Miles (nm)	Perp. Sighting Dist. (nm)	Common Dolphin	Striped Dolphin	Other Porpoise	Unidentified Porpoise
Far North Nearshore	2887	0.92	23	0	10	27
Far North Offshore	1016	0.44	8	0	9	3
North Nearshore	1825	2.51	3	1	2	8
Central Nearshore	7442	0.81	6	0	22	78
South Nearshore	2351	1.15	17	0	11	21
North Midshore	753	0.59	0	0	4	3
Central Midshore	2864	0.84	1	0	6	12
South Midshore	2812	1.23	5	0	5	14
Expanded North Offshore	690	1.78	0	0	0	5
Expanded Central Offshore	2802	1.00	3	1	0	16
Expanded South Offshore	25310	1.09	98	9	18	298
Far South Nearshore	1487	0.98	4	0	2	18

Table 7. Estimates of school densities (schools/1000nm^2) for the areas as in PSA/9. The grid system appears as in Fig. 1.

Section	Jan-Feb, 1975					Jan-Feb, 1976				
	Spot. Dolp.	East. Spin.	White Spin.	Common Dolphin	Strip. Dolph.	Spot. Dolph.	East. Spin.	White Spin.	Common Dolph.	Strip. Dolph.
North Nearshore	0.41	0.	0.17	1.93	0.21	0.96	0.19	0.	0.71	0.24
Central Nearshore	8.00	5.69	0.11	0.76	0.06	8.35	4.15	0.23	1.87	0.
South Nearshore	3.40	0.	2.72	5.56	0.	0.97	0.16	0.16	5.39	0.
North Midshore	4.20	0.	0.40	1.97	0.66	1.18	0.	0.	0.	0.
Central Midshore	2.52	0.54	0.24	1.52	0.13	1.93	0.39	0.20	2.89	0.
South Midshore	1.00	0.11	0.11	2.67	0.67	2.13	1.12	0.37	2.39	0.
North Offshore	1.60	0.74	0.	0.97	0.	5.52	2.76	0.	0.	0.
Central Offshore	3.20	0.62	1.29	1.40	0.44	4.14	1.66	2.49	2.54	0.85
South Offshore	2.64	0.28	0.28	3.84	0.24	4.26	0.27	1.25	6.00	0.55

Table 8. Estimates of school densities (schools/1000nm^2) for the expanded grid. Grid areas are as in Fig. 2.

Section	Jan-Feb, 1975					Jan-Feb, 1976				
	Spot. Dolph.	East. Spin.	White Spin.	Common Dolph.	Strip. Dolph.	Spot. Dolph.	East. Spin.	White Spin.	Common Dolph.	Strip. Dolph.
Far North Nearshore	0.66	0.13	0.	9.53	0.	0.29	0.20	0.	7.74	0.
Far North Offshore	0.	0.	0.	7.32	0.	0.	0.	0.	10.00	0.
North Nearshore	0.41	0.	0.17	1.92	0.21	0.96	0.19	0.	0.71	0.24
Central Nearshore	8.00	5.69	0.11	0.76	0.06	8.35	4.15	0.23	1.87	0.
South Nearshore	3.40	0.	2.72	5.56	0.	0.97	0.16	0.16	5.39	0.
North Midshore	4.20	0.	0.40	1.97	0.66	1.18	0.	0.	0.	0.
Central Midshore	2.52	0.54	0.24	1.52	0.13	1.93	0.39	0.20	2.89	0.
South Midshore	1.00	0.11	0.11	2.67	0.67	2.13	1.12	0.37	2.39	0.
Expanded North Offshore	1.60	0.74	0.	0.97	0.	5.52	2.76	0.	0.	0.
Expanded Central Offshore	3.21	0.61	0.56	1.40	0.44	4.18	1.39	2.79	2.54	0.85
Expanded South Offshore	2.18	0.25	0.25	3.84	0.24	2.28	0.10	1.34	6.00	0.55
Far South Nearshore	0.	0.	0.	4.62	0.	0.	0.	0.	5.26	0.

Table 9. Average number of porpoise per school ($\bar{x}$) and sample size (n) from shipboard surveys of 1974, 1975 and 1976.

Species/stock	1974		1975		1976	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Spotted dolphin	724	518.00	924	870.97	346	719.66
East. spinner dolphin	378	762.00	191	868.18	48	1029.73
Whitebelly spinner dolphin			88	352.03	65	337.00
Unid. spinner dolphin			263	581.38	86	434.35
Common dolphin			288	550.10	195	505.77
Striped dolphin			46	206.43	14	605.29
Bottlenosed dolphin			228	97.43	74	207.54
Rough-toothed dolphin			0	-	2	3.50
Fraser's dolphin			3	238.00	1	20.00
Risso's dolphin			25	24.56	15	6.93
Short-finned Pilot whale			143	26.11	64	22.76
Pygmy killer whale			0	-	0	-
Melon-headed whale			0	-	0	-

Table 10. Estimated sightings and sighting indices of bottlenosed, rough-toothed, and Fraser's dolphins and short-finned pilot whales

Species	School sightings (Number)[1/]	Number per school[2/]	Number sighted	Sighting indices [3/]
Spotted dolphin	1416	829.7	1,174,855	-
Bottlenose dolphin	711	124.4	88,448	7.53
Rough-toothed dolphin	5	3.5	18	- [4]
Fraser's dolphin	5	183.5	918	0.08
Risso's Dolphin	39	17.9	698	0.06
Short-finned pilot whale	206	25.1	5,171	0.44

[1/] Total sightings for 1975 and 1976. Included in the above sightings are 1137 sightings of unidentified porpoises prorated to common, striped, bottlenosed, rough-toothed and Fraser's dolphins.

[2/] Weighted average from Table 9.

[3/] (Number sighted/Number spotted dolphin sighted) x 100

[4/] Combined with bottlenosed dolphins; see text.

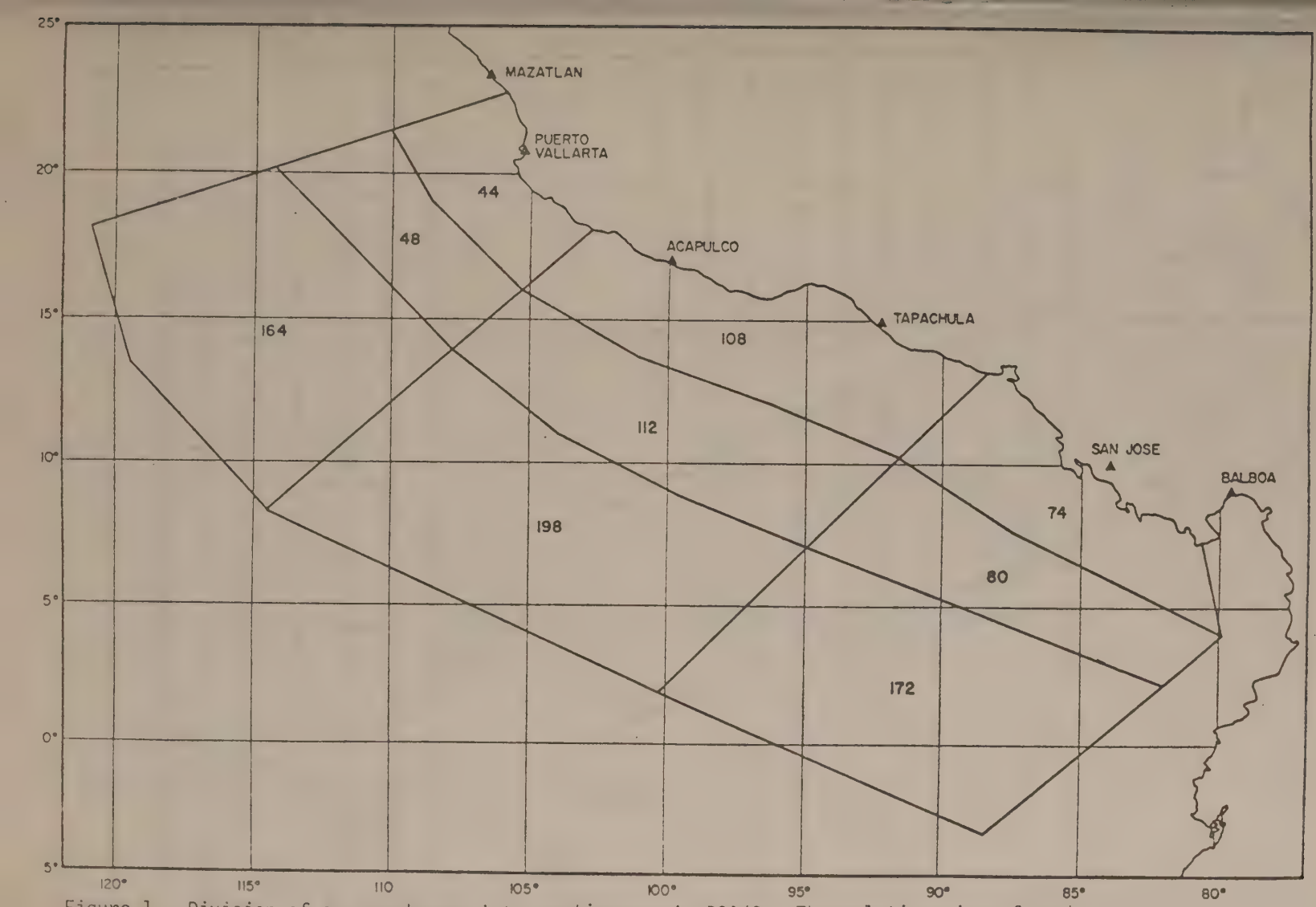

Figure 1. Division of surveyed area into sections as in PSA/9. The relative size of each section is indicated. The basis for this particular grid is given in PSA/9.

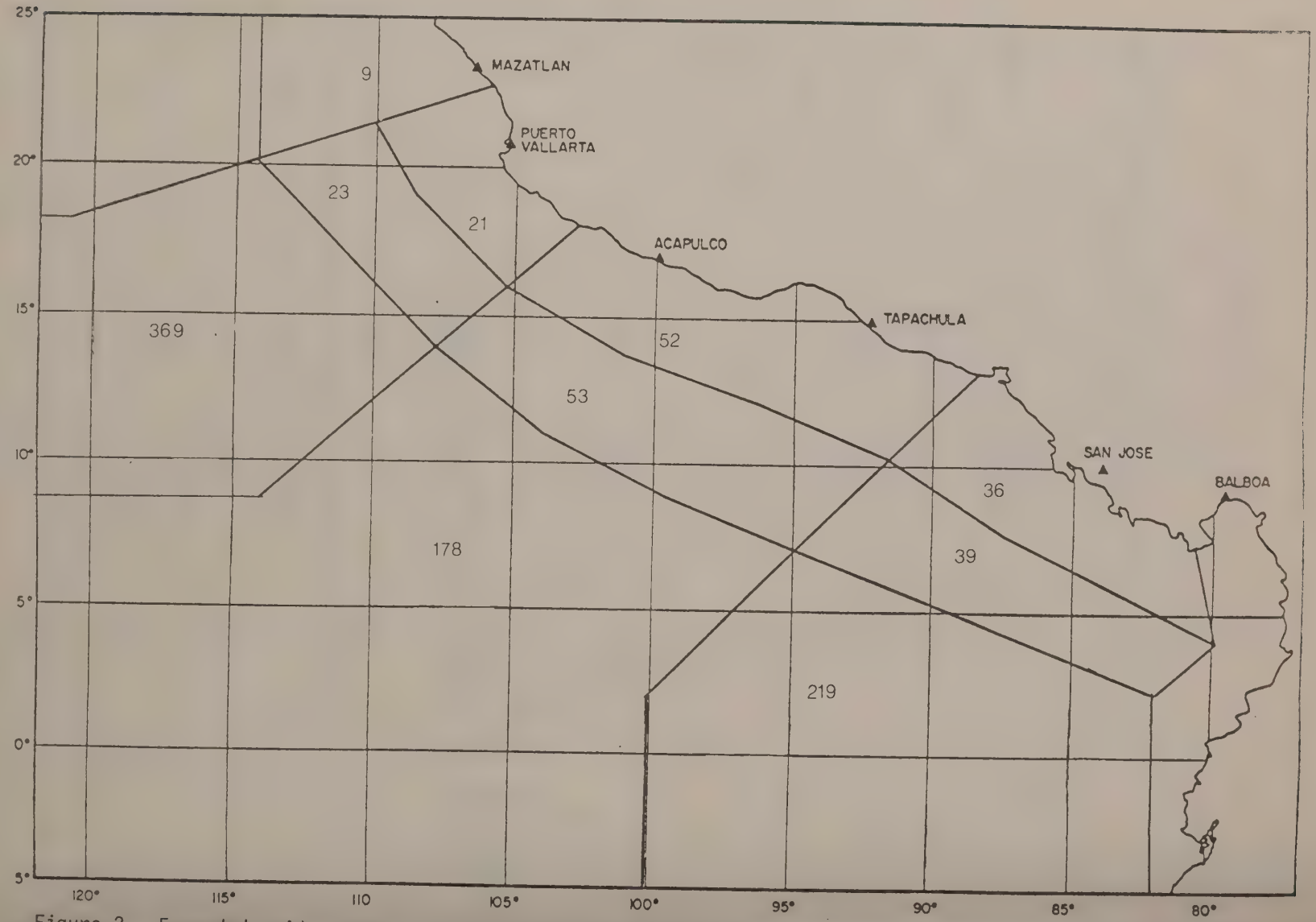

Figure 2. Expanded grid system including unbounded peripheral areas. The outer boundaries depend upon the stock of concern. The relative area in each section for the

APPENDIX 6

ESTIMATED INCIDENTAL KILL

Estimates have been made of the kill in the years 1971-1975 from data on the number of porpoise sets by vessel size class recorded by the Inter-American Tropical Tuna Commission (IATTC) and the kill per porpoise set recorded by National Marine Fisheries Service (NMFS) observers accommodated aboard U.S. purse seine vessels (PSA/1, PSA/8). For the purposes of this workshop, however, it was necessary to estimate the incidental kill of porpoises for the years 1959-1975, where 1959 is the major year of conversion to purse seining and setting on yellowfin tuna associated with porpoise. In addition, certain adjustments of the NMFS estimates for 1973-75 were made.

1959-70

IATTC single-set data files, developed from logbooks, were summarized to give the logged number of purse-seine sets by vessel size class, set type (porpoise and non-porpoise sets), and regulation status for the years 1960-1970. The logged catches of yellowfin and skipjack tunas for those sets were accumulated for each year. The total catch of yellowfin tuna and skipjack tuna by regulation status, species, and gear, as taken from unloading weights, were available from IATTC records for 1969-1970. Total catches for the years 1960-1968 were partitioned

by gear on the basis of logbook records. The ratios of total purse-seine catch (yellowfin plus skipjack) to logged purse-seine catch in the single-set data for the years 1960-1970 were multiplied by the logged porpoise sets to estimate the total number of purse-seine sets on porpoise. This procedure assumes that the single-set data file is a random sample of the total catch. The results are given in Table 1.

Single-set data were not available for 1959, so a different procedure was adopted. The 4 years prior to 1959 averaged 16,760 tons of yellowfin tuna caught by purse seine:

Year	Yellowfin tuna catch by purse seine (tons)
1955	12,679
1956	19,425
1957	15,055
1958	19,880
1959	28,187

Assuming that virtually all the 16,760 tons were caught in association with schoolfish and assuming that virtually all the increase in purse seine catch in 1959 was caught in association with porpoise gives by subtraction an estimate of 11,427 tons of yellowfin tuna caught in association with porpoise in 1959. It is not known how well the likely overestimate of yellowfin catch on schoolfish in the 16,760 tons is balanced by the likely underestimate of yellowfin catch on schoolfish in the 11,427 tons. Total porpoise sets for 1959 were estimated by the

ratio of yellowfin tuna caught on porpoise in 1959 (11,427 tons) to that of 1960 (62,767 tons) and the number of successful and unsuccessful sets in 1960 (Table 1).

The average kill of porpoise per set on porpoise is required to estimate total porpoise kill from total porpoise sets (Table 1). Table 2 gives the average kill per set recorded by NMFS field technicians for the years 1971-1975. A number of rules were developed to estimate the kill per set prior to 1971. The kill per set for unsuccessful sets was averaged over the years 1971-1975 within vessel size classes and the overall average (1.86) was applied to vessel classes with no data. The successful-set kill rate for the first four vessel classes was estimated from the average of the 1971 and 1972 kill rates of vessels of 201-300 tons and 301-400 tons, respectively. The kill rate of vessel class 401-600 tons was estimated from its 1971 and 1972 average. The kill rate of vessel class 601-800 tons was estimated from a linear regression of kill rate on years. The successful-set kill rate for the last three vessel classes was estimated from a regression of the pooled kill rates on years.

The total kill of porpoises 1959-1970 was estimated by multiplying the proper values of Tables 1 and 2 giving the central column 1962-1970 and the column designated as "lower" 1959-1961 (Table 3).

In the years 1959-61, the backing down procedure for releasing porpoises was being developed. The kill rates estimated in Table 2, however, are more likely to be representative of the kill rates obtained when backing down. Several observations made in 1960 by NMFS personnel indicate that about 700 animals were captured per set and about half, or 350, were killed per set on a vessel which did not back down. This is much higher than the 91 per set estimated by the first method. To examine the effects of this higher kill rate, we assumed that no backing down occurred in 1959, two-thirds of the sets involved no backing down in 1960, one-third of the sets did not involve backing down in 1961, and sets not involving backing down were insignificant in 1962 and beyond. This gave kills per successful set of 350 for 1959, 264 for 1960, and 177 for 1961. The column designated as "higher" in Table 3 is the estimated porpoise kill 1959-1961 using the higher kill rates.

1971-1975

The estimated porpoise kill 1971-1975 published previously was based on the assumption that the kills per set on non-U.S. flag vessels and U.S. flag vessels were the same. Since non-U.S. vessels are not directly subject to NMFS regulations and scrutiny and pressures within the industry, there is reason to suspect that the kill rate may be higher than on U.S. vessels. However, many non-U.S. vessels that are porpoise fishing are likely to have Medina panels, to have key U.S. crew members,

and to back down. Therefore, the workshop participants decided to use an intermediate assumption that the non-U.S. kill rate for 1973-1975 is the same as the 1972-1973 U.S. average. Adjustments were made for changing species composition, number of porpoise captured and amount of yellowfin caught per set. The revised estimated total kill 1971-1975 is given in Table 3 and by species in Table 4.

Table 1. Estimated total porpoise sets, 1959-1970, by vessel size class and set type.

Vessel size class[1]	Set Type[2]	1959[3]	1960	1961[4]	1962	1963	1964	1965	1966	1967	1968	1969	1970
51-100	S	-	32	6	0	0	0	0	0	0	0	0	0
	U	-	33	-	2	0	0	0	0	0	0	1	0
101-200	S	-	1051	1249	624	768	716	862	670	641	384	530	172
	U	-	866	-	807	819	596	532	516	246	246	292	99
201-300	S	-	1180	1626	806	881	1656	1878	1854	1350	1071	1488	689
	U	-	841	-	953	913	1435	997	872	407	494	572	297
301-400	S	-	908	934	332	624	1748	2088	1874	1194	873	1856	1778
	U	-	709	-	345	574	1121	937	582	254	239	438	306
401-600	S	-	45	135	72	33	396	494	697	324	633	1626	2239
	U	-	32	-	92	34	302	135	111	56	110	230	266
601-800	S	-	0	33	5	10	36	26	0	1	53	581	1210
	U	-	0	-	22	26	67	29	1	0	6	78	187
801-1000	S	-	0	0	0	0	9	1	45	1	115	762	871
	U	-	0	0	0	0	4	2	26	4	40	113	171
1001-1200	S	-	0	0	0	0	1	0	0	0	7	93	205
	U	-	0	0	0	0	1	0	1	0	0	19	59
Totals[5]	S	585	3215	3982	1838	2317	4563	5350	5139	3511	3136	6936	7166
	U	452	2481	4265	2222	2370	3527	2631	2111	967	1135	1742	1386

[1]Carrying capacity (short tons).

[2]S = successful sets (>1/4 ton caught)
U = unsuccessful set(≤ 1/4 ton caught)

[3]Not available by size class, see text

[4]Unsuccessful sets not avilable. Total estimated from successful-set ratio and total successful sets.

[5]Differences due to rounding.

Table 2. Estimated kill of porpoise per set on porpoise by vessel size and set type.

Vessel size class[1]	Set Type[2]	Year					
		Prior to 1971	1971	1972	1973	1974	1975
51-100	S	90.70	-	-	-	-	-
	U	1.86	-	-	-	-	-
101-200	S	90.70	-	-	-	-	-
	U	1.86	-	-	-	-	-
201-300	S	90.70	96.40	-	-	23.30	10.50
	U	1.86	-	-	-	-	-
301-400	S	90.70	-	85.00	31.50	19.80	38.00
	U	1.83	-	3.40	-	-	0.25
401-600	S	62.50	75.60	49.40	14.30	12.90	31.82
	U	2.89	-	4.80	0.05	4.30	2.41
601-800	S	38.95	-	37.30	24.70	18.60	21.40
	U	1.15	-	0.50	0.80	1.90	1.40
801-1000	S	58.87	62.40	-	15.20	23.40	18.72
	U	1.21	-	-	0.40	1.60	1.64
1001-1200	S	58.87	-	-	44.20	13.20	17.68
	U	2.10	-	-	0.10	1.60	4.59
1201+	S	58.87	-	-	-	-	11.82
	U	1.86	-	-	-	-	1.86

[1]Carrying capacity (short tons).

[2]S = successful set (>1/4 ton caught)
U = unseccesful set (≤1/4 ton caught)

Table 3. Estimated total kill of porpoise, 1959-1975, in thousands

Year	Estimated Kill (1,000's) Lower	Higher
1959	54	206
1960	295	853
1961	356	713
1962	169	
1963	213	
1964	407	
1965	475	
1966	449	
1967	311	
1968	262	
1969	529	
1970	492	
1971	319	
1972	348	
1973	217	
1974	120	
1975	181	

Table 4. Estimates incidental mortality 1971-1975 by species and/or stock using 1972-1973 US kill rate for 1973-1975 non-US kill rate.

Species/stock	1971	1972	1973	1974	1975
Spotted	185000	273000	120000	75000	106000
Eastern Spinner	130000	65000	74000	22000	26000
Whitebelly Spinner				18000	39000
Common[+]	4000	9000	23000	4000	8000
Striped[+]	339	848	232	403	1768
Bottlenosed[+]	46	114	31	54	238
Fraser's[+]	2	6	2	3	13
Roughtoothed[+]	2	5	1	2	11
Risso's[+]	3	8	2	4	16
Pygmy killer[#] Pilot Whale, Melon-head	0	6	7	6	7

[+]Kill of these species estimated in aggregate and allocated to species according to percent occurrence in the sample kill for all years 1968-1976.

[#]Kill estimated at the rate of 0.00074/porpoise set.

APPENDIX 7

ASSESSMENT MODELS

Three types of information are needed to determine the initial population size (i.e., prior to significant exploitation): (1) an estimate of the population size for any year, (2) a vector of annual kills, and (3) a vector of the net reproductive rate (births minus natural deaths per unit population). Given that the population size is estimated for year i, the population size for the previous year (i-1) can be calculated by

$$N_{i-1} = \frac{N_i + 0.5K_{i-1}}{1 + (r-m)_{i-1}} + 0.5K_{i-1} \qquad (1)$$

Where

N_i = population size in year i

K_{i-1} = kill in year i-1

r = birth rate

m = natural mortality rate

and $(r-m)_{i-1}$ = net reproductive rate for year i-1.

Similarly, the population size can be calculated forward in time by

$$N_{i+1} = \left[N_i - 0.5K_i\right]\left[1 + (r-m)_i\right] - 0.5K_i \qquad (2)$$

Estimates of population sizes were obtained variously for 1974, 1975, and 1976 from aerial and ship surveys (Appendix 5). Estimates of the annual kills for the period of exploitation, 1959-1975, were obtained from set, kill per set, and species composition data of the Inter-American Tropical Tuna Commission (IATTC) logbook records and National Marine Fisheries Service (NMFS) observer records (Appendix 6). The vector of net reproductive rates required more consideration.

Estimates of the natural mortality rate (9%) and gross reproductive rate (13% ±2%) were obtained for the offshore spotted dolphin at current population levels. These values give a range of 2% to 6% with a midpoint of 4% for the net reproductive rate. Assuming the population was in equilibrium prior to exploitation, then the net reproductive rate was zero at the initial population size. However, at least one additional observation on the net reproductive rate at an equilibrium population size intermediate between current and initial and an estimate of the effects of lags between changes in population size and response to that change are needed to accurately estimate the net reproductive rate vector. Lacking this information, three cases of the net reproductive rate vector were chosen which are likely to bracket the actual case (Table 1).

For other species and stocks either no information or only gross reproductive rates were available. The workshop participants decided that the best that could be done at present for the other species and stocks was to assume that models similar to those for the offshore spotted dolphin applied.

Table 1. Three cases of net reproductive rates expressed as percentages of the maximum rate

Years after initial exploitation	1-year lag	3-year lag	5-year lag
Initial year	0	0	0
1	10	0	0
2	20	0	0
3	30	10	0
4	40	20	0
5	50	30	10
6	60	40	20
7	70	50	30
8	80	60	40
9	90	70	50
10	100	80	60
11	100	90	70
12	100	100	80
13	100	100	90
14	100	100	100
15	100	100	100
16	100	100	100
17	100	100	100